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THE PSYCHOLOGICAL FOUNDATIONS OF EDUCATION SERIES

Problem Solving in the Classroom

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BRYCE B. HUDGINS

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PROBLEM SOLVING *in the* CLASSROOM

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Preface

ATTITUDES TOWARD the purposes of instruction in our elementary and secondary schools have undergone a series of changes during the present century, sometimes swift, other times scarcely perceptible except after a span of years. Early in this period the schools were characterized by a dogged insistence upon rote memorization of textbooks and factual lists often of great length which possessed little meaning for the pupil who was required to master them. Dominated as the schools were by faculty psychology, such an approach to instruction is not difficult to understand. The benefits of learning were to be found in the increased powers of the mind, which were believed to profit directly and automatically from disciplined study. The youth who devoted his intellectual energies to the thoughtful, logical analysis of mathematics was to be recompensed, not principally by his increased understanding of mathematics, but by improvement in faculties for clear thinking.

For many reasons, not all of which are known even today, and which in any event cannot be related here, the curriculum and goals and methods of instruction changed drastically in the aftermath of World War I. New emphasis was placed upon the development of educational tasks that were more consistent both with our growing knowledge about child development and with the spirit of a democratic society. One aspect of this "new education" was a heightened concern with modifying instruction in ways that are consistent with the development of pupils' intellectual abilities, foremost among which was problem-solving skill. There seem to be at least two central generalizations which were of consequence. One was a reaction against the long entrenched faculty psychology with its implications of "automatic transfer" of learning; the other was advancing awareness among educators that our society was in the midst of an age of change. Today's knowledge might be obsolete before it appeared in tomorrow's textbooks. The best service the school could render its students was not to communicate facts and information that would probably be outmoded before the pupil could apply it in his own life, but rather to develop with students general procedures that hopefully would be applicable to a broad range of problems confronting the average citizen. There was perhaps in all of this an unfortunate discounting of the role of knowledge in problem solving and a failure to understand that new knowledge is in most cases more readily acquired, retained, and applied by the person who has a thorough foundation of knowledge in any field of intellectual endeavor.

This brief text rests on the assumption that one of the teacher's principal functions and responsibilities is to guide his students in the intelligent application of knowledge to problems in the world of ideas. It assumes also, however, that this can be done only as students develop, by means of careful teaching and intensive independent study, clear, working conceptions of the facts, principles, and generalizations that hold together any body of knowledge about which they are asked to deal with problems.

Problem solving is not a method of teaching. It is a general attitude, a disposition toward inquiry which has as its goals the development of new ideas based upon older ones and the seeing of intellectual light where darkness lay before.

This book is for teachers. Its aim is to develop an appreciation of the centrality of problem solving in the instructional process and to provide what I hope its readers will regard as practical suggestions to implement problem solving in the classroom.

B. B. H.

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1

Problem Solving as an Instructional Objective

THE GREATEST EXPENDITURE of intellectual energy in teaching, if teaching is to be effective and is to make a significant difference in the lives of boys and girls, is probably allocated to preparation for the task of teaching itself. This preparation, or the development of strategy for teaching, includes as an essential element the specification of the teacher's instructional goals or objectives. Within limits, the teacher will accomplish with his pupils what he sets out to accomplish. Without goals which are susceptible of being stated in behavioral terms, and therefore capable of implementation, the teacher achieves little of moment.

An objective in teaching, as in business, athletics, the military, or elsewhere, is instrumental in shaping the activities of the teacher and of his pupils. It suggests that one body of subject matter is more suitable than another at a given time, it tends to dictate the kind of organization and presentation that is advisable, and it provides some direction for evaluating the learning that has occurred as a result of the activity of teaching.

The teacher who holds the development of problem-solving skill as an important instructional objective will behave differently than a teacher who does not have a similar goal. It is to these differences and the consequences for pupil learning of problem-solving behaviors that this book is primarily addressed.

NATURE OF PROBLEMS

A problem, in the sense in which we will use the term, can be said to exist when the learner's previous knowledge or patterns of behavior are insufficient or inappropriate to enable him to provide an acceptable solution. In such a case, solution becomes possible only as he acquires new knowledge or capitalizes upon relationships which have not been seen before.

A well-known experiment from psychology will illustrate the definition. Years ago Köhler studied the reasoning behavior of chimpanzees. One of his tasks involved placing fruit at a carefully determined distance from the animal's cage. The distance was great enough that, stretch as he might, the food eluded the animal's grasp. Inside the cage, also by design, were two bamboo poles well within the animal's perceptual range. He had previously had experience using such a pole to rake in food beyond arm's length, but in this situation, a single pole was too short to reach the goal. Even when this behavior was obviously to no avail, it persisted for some time. At great length, and after considerable unproductive behavior, the second pole was seized, and ultimately the chimpanzee discovered that the two could be fastened together (they were especially selected for that purpose) into a single pole which could be used to attain the goal object. The problem was solved.

Let us review the problem-solving effort because it contains the important elements of most problems with which we have to deal, and also because in it we find the germ of most of the topics about which we shall talk subsequently in greater detail.

1. *The existence of a problem was recognized.* The animal wanted food, was motivated to obtain food; from his behavior we might infer that a drive was present which could be reduced by solving his problem (that is, obtaining the food). The important fact is that the animal *behaved*, and behaved in ways which, over the course of observation, could be said to be intelligent. His behavior, by and large, was directed toward the means of achieving the goal.

2. *Previously learned behavior patterns constituted a necessary but insufficient condition for goal acquisition.* The ape was not a novice at locating food. He had had opportunities before, had learned from experience, to reach unaided for food or to utilize a pole as a rake. Behaviors of this order approximated the final solution but did not by themselves render it possible.

3. *The demands of the problem suggested the general dimensions of the solution.* In the final analysis, the missing link between the animal's accustomed behavior and his goal was reduced to a matter of length. One pole was insufficient, but it moved him closer to the goal. What remained to be discovered was some means of further extending his reach.

4. *The required properties for solution were available.* Two poles, very similar in appearance and function, were visually prominent. With a bit of imagination one can almost hear the animal ruminating as he eyed the two of them side by side, "There's a 'not long enough' lying beside another 'not long enough.' But they are *together,* and perhaps they'll make a 'long enough.'" There are two points to be made: (1) the animal had to discover a new relationship—fitting the poles together, and (2) this discovery was aided by the juxtaposition of the poles. The two obviously had to be *physically* present to make any solution possible, but their relationship to each other was equally significant in maximizing their *psychological* presence.

PROBLEM-SOLVING PROCESSES

It is difficult to separate the problem situation itself totally from the processes which function in solution, but we shall attempt to do so in order to highlight both aspects of the procedure. The reader will do well to bear in mind that the nature of the task or problem influences the specific behavior of the learner. *Conceptually,* the processes utilized in solving discriminably different problems may be highly similar, although their similarities may be obscured in observing the behavior of individuals engaged in solving problems in various subject matter areas.

We shall take our first look at the process of problem solving by focusing upon the behavior of Sultan (one of Köhler's chimpanzees) as he attempted to secure the far-removed banana.

1. *The learner's behavior was goal-directed.* A real problem existed for Sultan. He was hungry, but he had no direct means of obtaining food. Its lure was sufficiently strong to keep him occupied for long periods of time as he sought a means of securing the fruit. In the typical classroom it is not possible to capi-

talize upon drives as powerful as those for food or water. But the teacher will wish to construct problems in which the pupil sees some purpose for concentrating his energy. The teacher may wish to pose problems which are relevant to the everyday lives of pupils, although this is not requisite. Problems in many academic areas possess high degrees of intrinsic interest, although characterized only infrequently or incidentally by immediate applicability to real situations. The important thing to consider is whether the problem is sensible to the pupil and worthy of his attention apart from a desire simply to please the teacher or to do what is expected of him.

Wertheimer (1959) illustrated this point with the story of a nine-year-old schoolgirl who was experiencing great difficulty with her studies, and who had been recommended for placement in a home for children of low intelligence. The parents asked Wertheimer to examine the child. He posed problems for the girl which called for arithmetic skills similar to those which she had failed on the intelligence test, and some which were more difficult, but he set the problems in the context of concrete, practical situations. The little girl solved the problems easily and with little hesitation. They made sense, and important consequences (as far as she was concerned) hinged upon finding adequate solutions.

2. *The process was characterized by uneven advances toward solution.* It would be naïve to assume that progress toward the goal was accomplished in a series of unbroken steps. Sultan tried to prod the banana with one pole. When that failed, he abandoned the first stick and tried the second one. Periodically, he appeared to relinquish the task altogether, although he later returned to it. The first success in fastening the two poles together seems to have occurred accidentally (by trial and error), but the fact that it occurred only after a great deal of playful manipulation suggests that this success was not altogether inadvertent.

3. *Solution occurred only after a new relationship was developed between the two available bamboo poles.* Often in problem solving all the necessary facts or materials are known or otherwise present in the environment, but relationships among them which are instrumental in producing solutions are not immediately apparent.

4. *The response to the problem was reinforced.* When an individual behaves, consequences ordinarily ensue. If these consequences are satisfying in some way we say that the response has been *reinforced.* Much theory and research in psychology deals with the role of reinforcement in learning. Essentially what occurs is as follows: the individual responds to a situation in some manner which achieves his goal or leads toward it. When a similar situation arises in the future, the individual will be likely to respond in a manner similar to the one which was initially reinforced. Sultan's solution of fitting the two poles together was reinforced by his subsequent success in procuring food with his new implement.

THE TEACHER'S ROLE

In the final section of this introductory chapter we shall suggest some of the critical functions performed by the teacher who is trying to promote problem solving in his classroom. The reader will do well to note these functions carefully, for we shall return to them under various guises in several of the later chapters.

1. *The teacher supervises the selection of pupils' problems.* Teachers often originate problems for students, of course. Textbooks and workbooks, particularly in mathematics and the physical sciences, are replete with exercises and demonstrations which meet our criteria for a problem. There are several obvious advantages in using such materials if they are wisely selected. First, a great deal of time and effort are needed to construct problems of significant value. If such problems, carefully formulated and relevant to the purposes of the teacher and his pupils, are easily available, their use is certainly warranted. It is only when the instructional objectives of the teacher are relegated to a secondary role, while text exercises, relevant or otherwise, dictate the pupils' learning activities that we question whether the tail is wagging the dog. Second, such problems are usually constructed to demand application of recently learned principles. There is reasonable assurance that most such problems, if introduced at the proper time, will be within the range of the normally able student.

Frequently, however, the teacher requires pupils to develop and solve problems of their own as part of a general assignment. This is probably done more often by upper elementary and secondary teachers than by teachers in the primary grades. Reports, projects, and many other activities which are normally employed as part of a unit of study lend themselves to such problem-solving tasks. The teacher must be in a position to examine the work being undertaken by each pupil with two chief criteria in mind: (1) is the activity selected, indeed, a problem, that is, one that requires some original thinking on the part of the pupil, and (2) is the problem chosen one that can reasonably be handled under the practical limitations that exist? An inexperienced pupil may select a problem with more enthusiasm than wisdom. It is fruitless to begin a task which so far surpasses the pupil's ability, or demands so much higher a level of knowledge or technical skill than he possesses or can acquire in a reasonable period of time, or which requires space, time, and equipment that the teacher cannot provide, as to preclude any possibility of real success.

2. *The teacher provides guidance.* If the teacher fulfills his first function of helping students select appropriate problems, most of the effort required to solve them should come from the pupil. But there are times when the teacher must play a more active role. Sometimes this may consist principally of serving as a listening post as the pupil explores alternatives. Most of us know the potential value for seeing new paths to a goal as we are forced to organize our thoughts, and as we present arguments and alternatives in order to explain the problem to someone else.

The teacher must also assess carefully when it will be productive to instruct the pupil with a vital cue. When Köhler's chimpanzee was making little progress toward his goal, the psychologist seized one of the poles and inserted his finger in it in an attempt to demonstrate the principle which Sultan needed to apply to his task. Wertheimer, while investigating the thinking processes of children who were trying to find the area of a parallelogram, frequently encouraged them to focus on the specific difficulty of the problem by asking them to tell him what it was about the figure that disturbed them. Solution usually followed once the child understood that the parallelogram could be reconstructed as a rectangle.

3. *The teacher develops general problem-solving skills.* Problems are not frequently solved by accident. More often successful solutions ensue from carefully directed thinking. As the teacher encourages pupils to look for and to solve problems, he must also give thought to teaching general skills which are useful for this purpose. Salient among these are principles for analyzing a problem to determine its requisites, to select from previous learning those facts or generalizations which are most likely to be applicable, and means for evaluating the adequacy of a solution—for knowing when a problem is effectively solved.

4. *The teacher reinforces problem-solving behavior.* The implications of this dictum are far ranging. They include, but are not restricted to, specific reinforcers, such as a corrected set of problems or a nod or word of acknowledgment by the teacher. In short, if pupils are to take problem solving seriously, so must the teacher. The teacher must show by his own behavior that the gains in skill in thinking which can result from problem solving are worth both the time and effort required to achieve them. A pupil will not be long deceived by a teacher who gives lip service to problem solving, but who in fact demands prompt, precise "textbook" answers to questions. The difficulties associated with classroom management are likely to be increased by problem-solving activities. They involve considerable independence on the part of pupils. The teacher may shortly find that not all of his pupils are engaged on the same tasks simultaneously. Conferences between the teacher and individuals or small groups of pupils may take the place of large group instruction at some times. Obviously, the teacher who uses such practices in his classroom must have confidence that pupils are using their time to good advantage—neither wasting it for lack of appropriate skills, nor squandering it on the pursuit of worthless activities. Certainly not all classes inspire such confidence in the teacher at the beginning of the school year, and some, despite his best efforts, never will.

In this chapter we have emphasized the influence on classroom activities which is exerted by the teacher's instructional objectives, and we have suggested the development of problem-solving ability as a goal of central importance. By reference to an easily understood illustration from the work of Köhler, we have tried to make clear the essential elements of a problem situation, to identify some of the more general features of the processes involved in problem solving, and to indicate the major kinds of responsibilities imposed upon the teacher who wishes to work toward such an objective.

The ensuing chapters are intended to extend and elaborate upon the themes introduced here.

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The Pupil as a Problem Solver

Pupils exhibit a wide range of individual differences in their ability to solve school-type problems. This chapter is concerned principally with a specification of the nature of such differences. We will focus upon such topics as factors which are important in problem solving and characteristics which differentiate good and poor problem solvers. This attempt at specification will necessarily lead us to an elaboration of the process of problem solving which we began in the introductory chapter. While the chapter heavily emphasizes the nature of individual differences in ability to work effectively with problem situations, it also serves to sketch in the background for the three following chapters which are oriented to the problems of classroom teaching.

One of the most interesting and at least potentially fruitful lines of attack aimed at increasing our understanding of human thinking is to be found in the work of psychologists engaged in the simulation of problem solving. Newell, Shaw, and Simon (1963), for example, have developed an abstract model of problem-solving behavior in which a distinction is made between processes which propose solutions to problems and those which are useful in verifying solutions. Their work draws attention to the significance of steps in problem solving which reduce the range of alternatives from which the solver has to choose at each point. The heuristic they employ involves making the present state of the problem at each step more similar to the finished or required state than it was before. They have developed a general problem-solving program that they believe is probably applicable to the solution of a wide range of mathematical problems. This program has three types of goals: (1) change the original expression to the desired expression; (2) reduce the difference between the original and the desired expressions; and (3) apply an operator (a rule for changing an expression) to the original expression.

The work on computer simulation of problem solving is much too technical for us to deal with here in much detail. Two points about these efforts, however, seem to be worth making. First, they provide good demonstrations that human thought processes are susceptible to systematic analysis. Second, they emphasize the fact that effective problem solving is directed at changing the "givens" of the situation, perhaps through a long series of successive steps, to conform to the goal state or solution.

Duncker (1945) made these same points in what was perhaps a less precise way. He posed a problem to a subject and asked the subject to talk about his thought processes as he attempted to solve the problem. When necessary, Duncker would call the subject's attention to the fact that he was departing dramatically from the demands of the problem and would try to put him back on the right track. This kind of clinical analysis of thinking yields certain kinds of information about human thinking that are difficult or impossible to acquire in more formal experimental settings. The technique would seem to be useful, also, for classroom teachers who are interested in the individual diagnosis of pupils' problem-solving difficulties.

Probably the best known of Duncker's problems is the so-called "ray problem." The subject is informed that a patient is suffering from an inoperable stomach tumor. A ray is available, however, which at sufficient intensity will destroy human tissue. The problem is to find a way to use the ray so that it destroys the diseased tissue without damaging healthy tissue. For Duncker, the essence of problem solving lies in the subject's ability to conceptualize the "gap" between the given state and the goal state. When this gap is seen clearly, problem solving becomes a matter of changing the given situation in ways which fit the requirements of the goal state.

One of the persistent difficulties encountered by poor problem solvers is their inability to work within the limitations imposed by the problem situation. The ray problem, for example, makes it quite clear that the patient's tumor is inoperable. The subject must assume the validity of that assertion if he is to make progress toward the solution. Any suggestion which has to do with somehow pushing or cutting the patient's healthy tissue away from the tumor so that the ray can be directed at the tumor constitutes a dead end. In the same way, the solutions offered by some subjects to funnel the ray to the tumor through an aperture in the body are unacceptable.

When the subject behaves in terms of the demands of the problem situation, it becomes apparent that the ray must be administered externally, that is, that it will have to pass through the unaffected portions of the body as well as through the tumor itself. This requirement ultimately leads the solver to the recognition that somehow the intensity of the ray at various points within the body must be altered. What then remains to be accomplished is a practical solution to the problem, that is, how can one predictably change the ray's intensity in the way desired? The preferred solution is to project the ray through a lens in such a way that it is diffused both before and after it reaches the diseased tissue but focuses precisely upon the tumor.

CHARACTERISTICS OF GOOD AND POOR PROBLEM SOLVERS

The product of efforts at solving a problem may reveal little about the pupil's cognitive operations. To communicate to the pupil only that his answer to a problem is inaccurate or inappropriate is not of much use to him for altering his behavior, except in a very general sense. That information may encourage him to review his procedures and perhaps discover his own error, but it provides him with no guidance concerning either the magnitude of his mistakes nor the place at which they may have occurred. Similarly, the teacher's understanding of why pupils fail to solve problems successfully is not much advanced if only the end products of problem-solving activity are considered. Directions which many teachers give to their pupils to "show your work" or to "explain why you chose" a particular alternative seem well advised. Such explanations provide the teacher with information which bears directly upon the pupils' processes of thinking

Some years ago Bloom and Broder (1950) examined the problem-solving processes of two groups of college students. The students were differentiated on the grounds of academic aptitude test scores and college grades. One of the groups was composed of students who had high aptitude scores, and who had earned grades of A and B in their courses. The other group was characterized by low test scores and course achievement in the D and F range.

Each of the students was given a variety of problems to solve. These problems were taken from academic achievement examinations. The students were examined individually by one of the experimenters. Seated in a private room with only the experimenter present, the student was confronted with a problem that he was asked to solve. In addition to providing a solution to the problem, the student was also requested to talk aloud about his thoughts during the problem-solving session. The protocols that resulted from these sessions provided Bloom and Broder with the raw material to undertake a systematic analysis of the processes of problem solving, as well as aiding them to define and classify the similarities and differences in behavior between good and poor problem solvers.

To clarify the procedure employed by Bloom and Broder, one of their problems and the responses of several students to it are reproduced below. It should be noted that the protocols for individual students are virtually verbatim statements of what the students verbalized as they engaged in the problem-solving process. Undoubtedly, the students did not speak every word that crossed their minds during that time, because of lack of experience with the method or their self-consciousness about communicating to a stranger in such detail. Nonetheless, the protocols do tend to suggest the cognitive processes used by students while engaged in solving a problem, and they emphasize the back and forth flow of ideas, as contrasted with the point-by-point sequential consideration of elements in a problem which is commonly assumed to characterize thinking. Notice also the differences among the protocols in their completeness and adequacy. The statements are roughly scaled from least to most acceptable. We follow the presentation of these protocols with some discussion of their salient characteristics.

PROBLEM 1[*]

Rank the following life forms in the order of their appearance in the geologic record. *Blacken* the answer space *A* for the one that appeared first, etc.

	A	*B*	*C*	*D*	*E*
81. Mammals	☐	☐	☐	☐	☐
82. Sponges	☐	☐	☐	☐	☐
83. Amphibians	☐	☐	☐	☐	☐
84. Fishes	☐	☐	☐	☐	☐
85. Flowering plants	☐	☐	☐	☐	☐

Pauline M. (Score 0): [Read the directions–laughed.] "Something I don't know anything about–guess on all problems–seems plants would be first–don't know what the sponges are since I don't know sponges–would probably get them all mixed up–might say sponges second, only guessing–say amphibians–last, I believe, mammals and fishes–all guesswork, though."

Mary W. (Score 1): [Read the directions.] "Not quite sure I read the right thing, so reread the directions–don't understand if I'm to pick one of each of these for *A* or if *A* for the first and *B* for the second, and so on–haven't had biological sciences, so I'll just venture a guess–undoubtedly wrong–not mammals, or fishes–don't know amphibians–if that's what it is–say enny, meeny, miny, mo–and sponges–82 for *A*–assume if in front *A*, *B*, *C*, *D*, *E* rate them in order–don't know exactly what to do with the ones left over."

Val H. (Score 0): [Read the directions.] "*A* appeared first, *B* next, *D*–the period most recently–first 85–recall from biology, answer *A*–then 82 would be *B*–then not sure of amphibians or fishes–there were primitive fishes, but–say fishes third, then amphibians *D*, and then 81 *E* for I think they are most recent."

David F. (Score 1): "Rank. [Read the directions.] Does that mean phylogenetic tree–I know the phylogenetic tree better than the geologic record–mammals late in the animal kingdom–flowering plants late in the plant kingdom–sponges is the answer–check–mammals after sponges, sponges before amphibians, amphibians before fishes, fishes before flowering plants, sponges before all of them, so sponges first."

Ned M. (Score 2): [Read the statement. Read the alternatives, mispronouncing "amphibians."] "Mammals last and fishes next–no, mammals last–no, my biology course in the ninth grade–mammals, no flowering plants last because had cavemen and animals when only had ferns–third, phyla, and flowering plants in the fourth—then mammals, fishes, going backwards—flowering plants, mammals, fishes, don't know what amphibians are, but sponges are third from the bottom of lowest animal life, so amphibians last along with amoeba—amphi, amphi, can't remember."

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[*] Benjamin S. Bloom and Lois J. Broder, *Problem-Solving Processes of College Students: An Exploratory Investigation*, Supplementary Educational Monographs, No. 73 (Chicago, Ill.: The University of Chicago Press, 1950), pp. 9–12. Copyright 1950 by The University of Chicago Press. Reprinted by permission.

Bernice Y. (Score 3): [Read the directions. Read the alternatives.] "Fish before the land animals, therefore fishes first—no, sponges first, sponges on the cellular level of development—well, minimum of differentiation—then fishes, differentiated structures, gills—amphibians, the bridge—life from water to earth—flowering plants next, no, flowering plants are plants, rest are animals—either flowering plants or mammals last, no, not true—flowering plants late on the evolutionary scale—flowering plants 4, and mammals 5; very latest, highest degree of development."

This problem required that the student understand he was to rank the items in a specified order. Several kinds of information could be utilized by the student in arriving at the preferred order. He might remember the geologic record or the evolutionary scale. Lacking this information, he might attempt to differentiate the items on the basis of their complexity, whether land or water animals, or plant and animal forms. Given some such principle for sorting out the items, the student must still know enough about each of the items named to place them at the appropriate points in the sequence.

Pauline M.'s record is instructive for what it reveals about her effort to use some system for analysis even in the absence of very specific knowledge about the geologic record. Although her score is zero (she did not place any of the items in the correct sequence), and she repeatedly announces that she is guessing at the answers, she separates the items into plant and animal and assigns the first place to flowering plants.

Like Pauline, Mary W. protests her lack of knowledge about the geologic record and the fact she must guess at the answers. Both of these protocols testify to the critical role of knowledge in problem solving. Furthermore, Mary appears to have difficulty interpreting the directions of the problem.

We indicated earlier that attention only to the products of problem solving can severely limit the information the teacher gains about his pupils' thought processes. If Pauline M. and Val H. are considered together, their scores of zero suggest that neither was successful in solving the problem. Analysis of the protocols, however, would contradict such a conclusion. Val was highly successful in ordering the four types of animals. His error, placing flowering plants first in the geologic record, resulted in the misplacement of each of the animals, thus earning him a score of zero.

David appears to have lost track of the demands of the problem. Although he begins by reminding himself that the items are to be ranked, it is not clear that he followed through on this basis. To the extent that he was successful with the problem, his success seems to stem from his ability to translate the problem into terms that are meaningful for him, that is, about which he feels he has some useful knowledge. He equates the phylogenetic tree with the geologic record. Presumably, he would have solved the problem more adequately than he did in fact had he been able to use that translation appropriately.

The protocols of Ned and Bernice, and the scores assigned to them, indicate that these two students best understood the problem and solved it with the greatest degree of success. Bernice's answers, particularly, illustrate an attempt to make a systematic analysis of the demands of the problem.

As Bloom and Broder pursued their study of college students' thought processes, they developed four bases for use in the analysis of the protocols.[*]

1. Understanding of the nature of the problem.
2. Understanding of the ideas contained in the problem.
3. General approach to the solution of problems.
4. Attitude toward the solution of problems.

These four categories were found to be useful bases for discriminating the problem-solving behavior of students who performed successfully or unsuccessfully on a wide range of achievement-type problems of which the illustration used above is an example.

1. *Understanding the nature of the problem.* By understanding the nature of the problem Bloom and Broder have reference to students' ability to start an attack on the problem, that is, to make appropriate use of key words in the description of the problem and also in reference to the student's ability to solve the problem as stated. It is notable that the successful problem solvers in Bloom and Broder's sample demonstrated their ability to begin the attack on a problem. As they read the statement of

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[*] *Ibid.*, p. 25.

the problem they were frequently able to pick out some key word or phrase which enabled them to understand what the elements of the problem were. The unsuccessful solvers on the other hand would typically read the statement of the problem, perhaps reread it several times and comment that the problem either made no sense to them or that they failed to understand it. Some of the difficulty encountered by the nonsuccessful problem solvers in launching their attack seems to be attributable to the difficulty they had with the directions for the problem. The unsuccessful students frequently tended to read the directions of the problem with little evidence of comprehension. Other students seemed to fail to read the instructions or to read them in an indiscriminate way. This seemed often to be an effort on the part of these students to hasten or to shorten the time involved in problem solving.

Successful students, too, sometimes skipped through the directions, but they seemed to do this purposefully and in a way that helped them understand more quickly what the critical elements of the problem were.

The two groups also differed considerably in their abilities to solve the problem with which they were presented. One of the main difficulties encountered by the nonsuccessful problem solvers was that they undertook the solution of a problem, handled it appropriately, arrived at a correct solution, but the problem which they solved was not the problem which had been presented to them. Frequently, these students appeared either to have forgotten part way through what the demands of the problem were or to have failed, as was indicated earlier, to read the directions carefully and in a way that would help them to structure and to direct their attack upon the problem.

The reader may note the similarity in the foregoing with the earlier discussion of the difficulties encountered by some of Duncker's subjects in solving the ray problem. To the extent that Duncker's subjects failed to be constrained in their attacks upon the problem by the limits imposed through his instructions they tended to suggest solutions which might, under certain circumstances, be appropriate but which were invalid solutions in terms of the problem which he was asking them to solve.

2. *Understanding the ideas contained in the problem.* This category was concerned with the student's possession of relevant

information to solve the problems and perhaps more critically with his ability to see the possibility of transferring selected portions of his store of knowledge to the particular problem under consideration at the moment. As we might anticipate, the two groups of subjects used by Bloom and Broder performed differently with respect to this basis of judgment. The nonsuccessful solvers seemed often to be unaware of the fact that the knowledge they possessed could indeed be applied to the problem at hand. In some cases the student, while talking his way through a problem, would indicate that he simply did not have information at his command which he could use to solve the problem. However, upon probing by the investigator with some appropriate cues and suggestions, it often turned out that the student did as a matter of fact know the information which could appropriately be transferred to the problem. But without such assistance from the experimenter, it seems highly unlikely that the problem would have been solved. Indeed, the attitude of the nonsuccessful students seems to have been much more one of, "Unless I can look at the problem, and immediately see that I have information which will help me move directly toward the solution, there is very little that I can do to attack the problem."

A particular obstacle to the nonsuccessful solvers was encountered when the problem that they were asked to solve was formulated in terms which were unfamiliar to them. In these cases it seemed especially difficult for the student either to translate the concepts which were presented in the problem into terms with which he could deal or, conversely, to ask himself questions about what knowledge he had that might in some way be subsumed under the concepts which were presented in the statement of the problem. In some cases, also, the students had difficulty in using relevant knowledge at their command because of unfamiliar words; or, in some cases, statements of problems were so highly abstract that the student felt overwhelmed at being asked to suggest solutions to these problems.

Typically, the successful problem solver would hesitate, begin to ask himself questions aloud of what he knew that would help him to break down the problem into more manageable components, and then proceed with a reasonable chance and expectation of arriving at an appropriate solution. Nonsuccessful solvers, on the other hand, behaved characteristically as though there was very little hope that they would be able to arrive at a correct solution to the problem or that they even could make much of a constructive attack upon it at all.

3. *General approach to the solution of problems.* Bloom and Broder suggest three dimensions upon which the successful and nonsuccessful problem solvers differ in the way in which they approach the solutions of problems. These are: (1) the extent of thought given to the problem, (2) the systematic analysis of the problem, and (3) completion of a process of reasoning. The successful problem solvers tend to devote considerably more thought to the solution of a problem than do the nonsuccessful students. Bloom and Broder describe these differences between the successful and nonsuccessful solvers as differences in activity versus passivity in the approach to the problem. As seen in the previous section, the successful solver approaches the situation as though it represents a problem, that is, a statement of conditions which he must reorganize or restructure and to which he must bring to bear knowledge in his possession in order to reach the stated goal. The nonsuccessful solver, on the other hand, seems to take the position that there is a pat solution to a problem which will either be evident to him upon reading the problem or, if it is not, will represent a difficulty which he cannot overcome because he does not have the information or the skill necessary for solution.

The successful solvers also tend to be more systematic in the way in which they work toward the solution of a problem. They attempt to break the problem down into subproblems which they will find more manageable, to simplify, to reorganize the demands of the problem, and then to begin in a systematic fashion to bring relevant knowledge to bear in helping them to arrive at a conclusion, or to help them to select an appropriate solution to the problem. Students in the sample of Bloom and Broder who were less successful in reaching solutions to the problems did not make such analyses. Rather they tended to dive into the problem head first, as it were, in an effort to solve the total problem. These students also were found to be easily distracted in their attempts to solve problems. External considerations such as extraneous words mentioned in the statement of the problem would sometimes lead them to rather extended digressions, from which it was very difficult for them to return to the point of the problem. Finally, the students differed with respect to how thoroughly they carried through to completion the line of reasoning with which they began the solution. The nonsuccessful solvers were much more likely than the successful students to abandon the plan for solution with which they began, although their original plan, if carried through, might well have led to a valid solution to the problem.

4. *Attitude toward the solution of problems.* The successful and nonsuccessful problem solvers also differed from each other in the attitudes which they held toward the solution of problems and toward the problem material. These differences are described as including attitudes toward reasoning. The nonsuccessful problem solvers tended to take the position that reasoning is of relatively little value in solving problems, that one either knows the solution to the problem or does not. Furthermore, the nonsuccessful students had less confidence in their ability to solve the problems than did the more successful problem solvers. Finally, there was a difference between the two groups in terms of the frequency with which they introduced personal biases or other personal considerations into their problem solving. In this regard the nonsuccessful student was sometimes heard to say, in arriving at his solution to a problem, that although one alternative might logically follow from the argument presented it was not his personal choice, and he would select an alternative which was congruent with his biases. Such decisions on the part of the nonsuccessful problem solvers tended to render invalid solutions to the problems because they ignored or otherwise violated restrictions imposed by the instructions given with the statement of the problem.[*]

These college students were examined again later during the year, and the investigators noted that some progress occurred in the ability of the students to deal effectively with similar problems. Bloom and Broder also point out that the greatest gains occurred along the dimension of increased information, and they suggest that lack of information is probably the difficulty facing the poor problem solver which is easiest to overcome. In the several chapters which follow, we turn our attention to classroom conditions which facilitate the problem-solving behavior of pupils.

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[*] *Ibid.*, pp. 25–32.

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The Teacher and Problem Solving: Classroom Management

It seems to be not only legitimate but necessary, in examining the issues of classroom problem solving, to discuss group functioning. The most apparent characteristic of typical teaching-learning situations is that they involve groups of students under the direction of a single teacher. The skill with which the teacher controls and manages the classroom group is an explicit determinant of his success in teaching, although such skill may be in large part independent of the teacher's subject matter sophistication and of his understanding of the learning process.

Many investigators, particularly social psychologists and sociologists, have been concerned with the behavior of groups and of individuals operating as members of groups. Some of the questions these social scientists have posed, as well as their analyses of group functioning, will be of interest in our discussion of group problem solving and in the subsequent section, where we examine the influence of the classroom social environment upon problem solving.

We begin this chapter with an example from an arithmetic lesson in order that the reader may see how group problem solving ordinarily occurs in the teaching-learning situation. Later we will describe typical experimental arrangements for such problem solving and then compare and contrast the two settings, trying to suggest ways in which the generalizations from social science research are useful to the classroom teacher.

The class on which our illustration centers is located in a lower middle socio-economic status area of a large city. There are thirty-two boys and girls under the supervision of Mrs. Brown. In general, the class is average. Most of the pupils have made normal progress thus far through school. Several are a year or two retarded in academic achievement. A few seem to be capable of much more demanding tasks than those confronting them. Despite these individual differences, however, all pupils are given the same work to do, although the teacher clearly expects better performance from some pupils than from others (all work completed in a shorter time, neatly, and with fewer mistakes).

Mrs. Brown is an experienced teacher. She has taught for twelve years, the last five in the school in which we now find her. She is regarded as an excellent teacher. Her relations with pupils, parents, and staff are easy and unstrained. Discipline in the classroom is maintained by the friendly but firm attitude of the teacher. The atmosphere of the classroom is clearly task-oriented but low pressure. It is as though the teacher were saying, "We're all here to work and to learn, but we're in no hurry. There is world enough and time."

The central topic in arithmetic which this class has been pursuing is fractions. A great deal of careful preliminary teaching has preceded today's lesson in problem solving. For example, concepts of *fraction, numerator, denominator,* and *mixed number* have been developed. Pupils have learned that only like fractions can be added or subtracted, and that only the numerators are used in computation. They have also been taught principles for, and have had some practice in, finding least common denominators and reducing fractions to lowest terms.

A concomitant goal of the arithmetic program is the development of skill in problem solving. During the current week the class has studied the textbook presentation of steps in solving a problem, they have had discussions, led by the teacher, of how to use these steps, and they have worked some problems independently, trying to apply the steps.

Mrs. Brown's plans for today call for reviewing the steps, working a series of problems in class, and then assigning a set of problems for the children to work by themselves. Tomorrow these problems will be placed on the board by various members of the class, each will be explained orally, and Mrs. Brown will look for the common mistakes in order to clarify them.

As we observe today, Mrs. Brown stands in front of the class, a teacher's edition of the arithmetic text in her hand. At their desks, each of the pupils has his book opened before him to a common page.

The teacher begins by reviewing the problem-solving steps that have been learned earlier and reminds the pupils to make use of them in working the new problems. Then she proceeds to the work at hand.

"Well, now, I think we can start. Let's take turns reading the problems aloud, and we'll work them as we go along. Who wants to begin?"

A flurry of hands are raised. Mrs. Brown recognizes David, a small boy seated near the front of the room.

David reads. "A dry goods merchant has a bolt of cloth 7⅔ yards long. He has promised a customer to save 4½ yards. Another customer wants to buy 2⅔ yards of the material. Can he make this sale and keep his promise to the first customer?"

David finishes reading. There is a brief pause. Then he says, "I don't get it." Others murmur assent. One or two hands are raised tentatively.

"Well, David, think about it for a minute. Marie, can you help him?" asks Mrs. Brown.

"I think he can," says Marie, "because he has enough material for both of his customers."

"All right, David, Marie says he can make both the sales. Do you agree with her?"

"Yeah, I guess so," David replies.

"Show us how you found out, David," Mrs. Brown asks.

David stares at his book, not looking up. After a moment the teacher says, "O.K. We'll ask somebody else. Who can tell us if Marie is right?"

Jean raises her hand, is called upon, and says, "You find out if 4½ yards and 2⅔ yards will come out of 7⅔ yards. And it will, so Marie's right."

"Yes," says Mrs. Brown. "Everybody see that now? What do we do?" she asks, walking to the blackboard. "We're going to *add*, aren't we? What do we add, David?"

"4½ and 2⅔."

"Yes, will you add that for us?"

David goes through the process of locating a common denominator and computing the sum. Another pupil volunteers the fact that David's 7⅙ yards are subtracted from the merchant's 7⅔ yards and that since ½ yard remains the merchant can oblige both customers.

The teacher completes this instructional cycle by calling for questions and settling the minor issues that are raised. The class then moves to the next problem; essentially the same cycle is repeated four more times. Marie, Jean, the pupil who completed the first problem, and one or two others are active in most of the discussion. Several of the pupils never participate, voluntarily or otherwise, although Mrs. Brown makes it clear that all contributions are welcome.

Five minutes before the end of the class, Mrs. Brown breaks off the discussion and tells the pupils the assignment for the next day and how to proceed with it. As our observation closes, the pupils are beginning to work on the assigned set of problems.

Prior to our examination of experimental studies of group learning and problem solving, it may be advisable to analyze Mrs. Brown's goals for her class, her means of reaching these goals, and some of the assumptions upon which her method is based. The simplest statement of the teacher's goal in this lesson seems to be the development of problem-solving skill among her pupils, and the activities of the class can be viewed as the means through which this goal is to be achieved.

Clearly the teacher recognizes that the pupils require some kind of guidelines for the solution of arithmetic problems. A heuristic has been provided by the textbook and class discussion, but the effects of such guides, particularly if they are applied rigidly and mechanically, are dubious. We shall consider this point in more detail in the next chapter when we discuss methods of teaching skills in problem solving.

Notice that Mrs. Brown takes great pains to insure that the sample problems are thoroughly discussed in class, the means of solution are elaborated appropriately, and any questions or confusion expressed by pupils are dealt with patiently, even willingly. Thus she views the final solution to these problems as group solutions, representing the cognitive activity and understanding of the class as a whole. Her assignment of an additional set of similar problems to be solved by the pupils independently strongly implies that she anticipates facilitation of such solutions to stem from the group problem-solving session. In short, Mrs. Brown assumes that positive transfer between the group and individual problem-solving contexts will occur.

We appear to have attributed to Mrs. Brown's practice both a consciousness or awareness and a deliberateness which it may not possess. The forces which actually shape her teaching behavior are very private and can only be guessed at by the observer. It may well be that Mrs. Brown herself would be unable to explain with any precision why her lesson proceeded as it did. Her presentation may reflect her interpretation of suggestions proffered by the teacher's guide or "common sense" may have directed her behavior or something else. Nevertheless, if our analysis of her goals, means, and the assumptions underlying them is accurate, any conflicting statement by her about her purposes or intended outcomes is in one sense irrelevant.

EXPERIMENTAL STUDIES OF GROUP PROBLEM SOLVING

Let us turn our attention now to a consideration of some recent research on group learning and problem solving. While the studies to be presented do not replicate the teaching-learning situation in Mrs. Brown's classroom, they do illuminate the questions we raised earlier about problem solving in groups.

Gurnee (1962) has reported the results of a most intriguing series of experiments on group learning. In most of his experiments, Gurnee tried to capture some of the flavor of ongoing college classes, that is, his subjects were undergraduate students from various psychology classes who were brought together in an ordinary lecture room for experimental purposes. Gurnee's principal concern in this inquiry was with the conditions which govern the development of group culture.

His general method was as follows. Groups of undergraduates assembled in the classroom to participate in studies of learning. A number of groups were used in different investigations, ranging in size from 35 to slightly more than 100. At the front of the room, Gurnee placed a bolthead maze containing 20 choice-points. This maze consisted of 20 pairs of brass roundhead bolts which were situated four centimeters apart. The pairs of bolts were arrayed vertically on a black fiberboard panel. A six volt lamp was situated halfway up the panel and just to the right of the boltheads. One bolt from each pair was wired to the lamp and to a brass pointer. Thus when contact was made by the pointer with the "correct" member of each pair of boltheads, the lamp would light, confirming the learner's response. Which member of each pair would be hooked to the lamp was determined by the toss of a coin, except for necessary adjustments to insure that an equal number of boltheads were selected from each column. The problem for the group was to indicate to the experimenter the "right" choice from each pair of boltheads, and learn, over a series of trials, which of each pair of boltheads, when contacted, would illuminate the bulb.

The experimenter asked the subjects which was the correct choice for each pair in turn: right or left? Selection of the group choice was based upon voice vote and a hand vote was requested only if the experimenter could not determine from the vocal statements where a majority of the votes lay. Six trials were conducted with each group and, as would be expected, scores on the first trial were at the level of chance. By the sixth trial, the groups tended to have mastered the sequence of choices. Typical intraserial learning phenomena occurred, that is, the groups learned the correct choices first for the several pairs presented early in the series, they learned the final few items next, and most inhibition occurred with respect to the intermediate pairs. There was also considerable variability among individuals in the speed with which the maze was learned.

One of Gurnee's experiments dealt with comparisons of the learning of individuals in a group (or classroom discussion type) situation and individuals in isolation. Two sets of 50 students, matched on the basis of sex and intelligence, served as subjects. One set constituted a group and went through a series of experimental trials much like those described above. The other 50 subjects were tested individually. They were treated exactly like the group members except that their learning was accomplished in the presence only of the experimenter.

All subjects, group and individual, were given six trials to learn the maze. Before each trial, the subjects indicated on a mimeographed sheet their series of choices. The sheet was collected, and the trial was run.

When the results of the two sets of subjects were compared, the members who functioned as a group committed significantly fewer errors on the average than those studying in isolation. No differences occurred on the first trial, but by the third trial the mean differences departed significantly from each other, increasing in magnitude through the balance of trials. Variability in error scores between the two groups was also different by the final trials, being lower for group than for individual subjects, and suggesting that the less able members profited most from the group situation.

Gurnee's experiment appears to provide at least some evidence in support of the teaching practices we saw in Mrs. Brown's elementary arithmetic class. It seems reasonable to infer from Gurnee's data that more of the pupils in the arithmetic class would arrive at the correct solution to the cloth problem as a result of the class discussion and explanation of the questions than if each were pursuing the task independently. Ultimately, however, teachers are interested in changes in individual pupil behavior. Does group participation enable pupils to solve other similar problems when working alone? This is a question that cannot be answered by Gurnee's study.

Several years ago this author (Hudgins, 1960) conducted an experiment designed to explore a similar issue. Fifth-grade girls and boys were given a series of arithmetic problems to solve on several consecutive days. Half the pupils were placed in small groups to work together at finding answers to the problems. We might equate this condition very roughly with the group situation in Gurnee's experiment and with Mrs. Brown's discussion method. The other half of the children solved the same sets of problems, but each child worked by himself (although in the presence of others). This is similar to, although not identical with, Gurnee's "alone" condition and is reminiscent of study periods in the classroom. Comparisons between the group scores and those of sets of matched individuals showed that the group consistently solved more of the problems correctly than the individuals. This finding appears to be in agreement with Gurnee's statement that his group subjects committed progressively fewer errors than the isolated subjects over the series of trials.

Finally, an additional set of arithmetic problems was given to all the fifth-grade pupils to work on by themselves in an effort to answer the question suggested above: Do pupils learn problem solving skills in a group situation which they can transfer to individual tasks more effectively than they learn such skills if working alone? Results of the posttests indicated no significant differences among pupils in their ability to solve problems which were attributable to the experimental treatments.

Our discussion of group problem solving can be summarized into a brief series of generalizations:

1. Based on a body of experimental data (for example, Gurnee, 1962; Hudgins, 1960) teaching practices in the area of problem solving which involve group discussion and participation can be expected to yield results superior to individual problem solving by class members.

2. Current evidence suggests that when the area of examination is the ability of *individuals* to solve problems the results are likely to be independent of the teachers' methods of promoting problem solving if these methods can be dichotomized as "group" and "individual" methods. Note that this conclusion does not suggest the absence of individual learning under either condition, but simply that one does not appear to be superior to the other when the criterion is the problem-solving skill of pupils working independently.

3. Changes in problem-solving skill of the order we have described probably depend most heavily upon pupils learning methods of comprehending the point of problems, analyzing problems into components, and selecting and applying to the problem the appropriate skills and knowledge to facilitate solution. Any method, "group," or "individual," which emphasizes such skills as part of the process of problem solving, and which provides practice in their execution, should in the long run prove superior to procedures which concentrate solely upon solutions to individual problems without regard for skills which are gen-

eralizable across types of tasks. This issue will receive fuller treatment in the following chapters.

SOCIAL ENVIRONMENT FOR PROBLEM SOLVING

Intellectual activity cannot flourish under circumstances which demand rigid conformity. When insistence upon the completion of tasks within specified limits of time, for example, takes precedence over consideration for the pupil who desires to reflect upon problems, perhaps to explore alternative means of solution, restriction in the flexibility of pupils' behavior must be anticipated.

Similarly, awareness by pupils of problems is facilitated by a classroom environment in which pupils are expected to raise questions, even though the questions may sometimes tend to introduce a digression from the mainstream of the lesson. The author once observed an intermediate grade social studies class which was discussing Alaska. The teacher's method was a very simple one, involving pupils in paragraph-by-paragraph oral reading of the geography text, followed by questions from the teacher directed at checking the pupils' comprehension of the lesson. Midway through the recitation, one of the boys raised his hand and, when recognized by the teacher, inquired how Eskimos could possibly eat whale blubber. A tone of revulsion was evident in the boy's voice, together with the implication that anyone whose diet departed from standard American fare was suspect and probably somewhat less than human. To this obvious invitation to help her pupils understand something of the impact of the natural environment upon the development of customs, and its control over differences among cultures in the ways they handle universal problems, the teacher responded with an impatient wave of her hand and the statement, "That's their problem!" Then she nodded to another pupil to continue reading. One would have to be naïvely optimistic to anticipate that pupils in this classroom will very frequently introduce questions or problems which deviate markedly from the prescribed activities of the curriculum.

In "The Emperor's New Clothes," Hans Christian Andersen reflected allegorically the powerful influence exerted on the judgment of individuals by society. Word spread over the kingdom that the emperor would lead a public procession clothed in the finest new raiment, but raiment which was invisible to anyone who was stupid or who was otherwise unfit for the office he held. On the appointed day of the procession, the people who lined the streets praised the beauty of the emperor's new wardrobe to each other, although privately they were appalled that they could see nothing. It took the innocence of a young child to comment frankly and devastatingly, "But he has nothing on!" Psychology has recently begun to verify the generalization which Andersen expressed so charmingly more than a century ago. We shall present evidence from several sources which deals with the impact on the individual's decisions of an erroneous but unanimous group judgment. These investigations have been chosen for discussion because they seem to bear special relevance to classroom problem solving. After presenting the studies, we shall try to indicate their applicability to the practice of teaching.

Asch (1960), in a study widely cited in social psychology, used a very simple experimental procedure to investigate the effect of a majority opinion on the behavior of one individual. Small groups of college students were brought into the laboratory, ostensibly for the purpose of assisting the experimenter in readying materials for research on perception. The tasks used in the experiments were sets of lines or other geometric forms. Subjects were told that they were to look carefully at the several lines shown simultaneously and decide, in each instance, which of them was the longest. In actuality, the lines were of easily discriminable lengths, so that it was highly improbable that anyone would have much difficulty in deciding independently which line was the greatest in length.

The several subjects were seated in a semicircle, the sets of materials were projected before them, and the experimenter, in a very routine manner, proceeded to ask the individuals in turn to give their judgments orally so they could be recorded. After several trials on materials of different kinds, the subject seated at the end of the semicircle—that is, the person who would be asked last to express his judgment—was discomfited by noting that the first person in the row, followed without exception by the others, named the wrong object. Unknown to the test subject, the other members of the group were confederates of the experimenter, and they were, on cue, deliberately supplying unanimous but incorrect responses to the stimuli. The test subject also had to respond, and his responses furnished data for the experiment.

A number of trials were conducted with each group. After the first "critical trial," as described above, the confederates responded honestly to several more sets of stimuli, followed by another critical trial. This procedure continued until the experimenter had several opportunities to observe the behavior of the test subject under group pressure.

Not all the test subjects behaved in the same way. Some "yielded" frequently, that is, they changed their original judgment to conform to that expressed by the other members of the group. Others yielded infrequently or not at all. Of particular interest are the self-reports of some of the subjects who yielded consistently. Many of them reported that they were convinced that the majority was wrong, but they conformed to the judgment because they did not wish to be alone in voicing a response. Others, however, changed not just their response but apparently were convinced after hearing the majority opinions that the wrong response was in fact the correct one.

The frequency with which test subjects yielded dropped sharply when, as a variation on the general procedure, one other member of the group reported an accurate response. Evidently, it is not the fact of being in the minority which induces individuals to conform to group pressure, but constituting a minority of one which has the most potent effect.

As part of a long-term, complex inquiry into human personality and behavior, Crutchfield (1962) has recently summarized a series of his investigations concerned with conformity and creativity. Crutchfield sees conformity as the enemy of creativity. In the research discussed here, Crutchfield operationally defined conformity in much the same way as Asch, that is, as the frequency with which an individual yields in his judgment to the opinion of a unanimous majority. Crutchfield's procedure and his materials, while not identical to those employed by Asch, are so similar that we will not describe them in detail. Crutchfield used a wide range of subjects in his experiments on conformity, including samples of military officers, college students, and industrial research scientists. He found differences in the frequency with which subjects yielded to majority judgments both between different occupational groups and within such groups. For instance, most yielding occurred within the sample of military officers as a group, and yielding was least frequent among the research scientists. Crutchfield suggests that military officers are not primarily selected because of their creative potential, but creativity is of central importance for scientific investigators. However, when within a given group the rated creativity of those who are most conforming is compared with the rated creativity of those who are least conforming, substantial differences occur between the two subgroups, revealing that the individuals who have been rated highest on creativity tend to conform to the group judgment significantly less often than the individuals who have been judged as less creative.

Crutchfield's analysis of personality differences between more and less conforming individuals is also instructive. Compared with more independent individuals, conformers tend to be less intelligent and more rigid in their cognitive processes. They are more anxious and less able to function effectively in crisis situations. The conformist tends to lack self-confidence but also to have a less accurate self-concept than the nonconforming individual. In interpersonal relations, he is passive and dependent at the behavioral level but is at the same time more suspicious and distrustful in his attitudes toward others. His personal attitudes and values are likely to be more conventional and moralistic than those of the independent individual. The conforming person may be rigid and authoritarian in his views.

Maier (1952) has demonstrated experimentally that the minority member or members of a group can contribute markedly to improved solutions of problems facing a group, and that they do so reliably and significantly under certain leadership conditions. Maier constituted thirty-four groups of college students, with five or six members in a group, in which one member was elected to serve as a discussion leader. Thirty-three other groups selected one of their number to function as an observer. All the groups were given the same problem to solve: A man bought a horse for $60 and sold it for $70. Then he bought it back for $80 and sold it again for $90. How much money did he make? The correct answer is $20, and the most frequent incorrect solution is $10. In all the groups, members were first given the problem and asked to solve it individually and to record their solutions. Group discussion took place and, after the discussion, members were again asked to record the solution that they now thought was correct.

Analysis of the first solutions showed no difference between the "leader" groups and the "observer" groups. About 45 per cent of the members in both types of groups arrived independently at the correct solution. The statements of final solutions, however, revealed a significant difference between the two conditions. Observer group solutions rose to about 72 per cent; correct solutions for leader groups increased to almost 84 per cent. Most of the difference between the two sets of groups was attributed by Maier to the fact that the leaders of discussion groups made it possible for all members of the group to participate in the discussion, thus insuring that a minority member who had arrived at the correct solution had an opportunity to be heard by other members of the group. In the observer groups, on the other hand, majority members tended to dominate the discussion, rendering it more difficult for a minority group member to present his argument.

The implications of these studies for teaching seem to be straightforward, but it is not difficult to think of classroom situations which impose severe limitations on the applicability of the principles. The research cited above suggests several generalizations for teachers.

1. A pupil may find it easier to keep new or unusual ideas to himself in the face of a social environment which is unsympathetic to departures from routine procedures or ways of looking at questions.

2. Creative pupils are less likely to be intimidated by opinions or problem solutions which are contrary to their own. Crutchfield's data suggest that less creative pupils, those who would profit most by being encouraged to find new ways to solve problems or by introducing original but not widely held points of view, are likely to find it easy to conform to majority opinions or to adopt popular solutions to problems.

3. An extrapolation from Maier's experiment suggests that the quality of thinking by the classroom group as a whole can be improved if the teacher consistently and systematically is at pains to allow each pupil to present his arguments in a climate

of mutual respect among pupils and between teacher and pupil.

To know these principles and to understand how they may be applied in teaching are two different things. The teacher who begins with the assumption that any statement or opinion a pupil may care to introduce into a class recitation is legitimate will soon learn that the flow of irrelevant and impertinent comments interferes with rather than facilitates the attainment of instructional goals. Similarly, the teacher who tolerates all questions—for example, about how an assignment is to be completed—will find that pupils are adept at formulating the most trivial, repetitious questions about minutiae that would never occur to the teacher. In short, the teacher who tries to apply the generalizations enumerated above without qualification will find that they do not work. The most likely result of such a discovery is that the teacher will reject the principles and concentrate on classroom management procedures that yield a semblance of order and progress toward goals in the activities of the classroom.

Our educational system is structured so that instruction occurs in groups. This fact in itself carries many and important implications for the teacher. Group instruction implies that organization is necessary in the classroom, organization to establish routine procedures for accomplishing everyday tasks. These procedures may not be important as ends in themselves, but they acquire significance because it is through them that the important business of imparting knowledge and of developing the intellectual abilities of pupils is facilitated. If the teacher has clarity about the goals he wishes to achieve, pupils can learn to discriminate between situations in which it is appropriate to question, to speculate, and to introduce or try out new ideas, and those where one's behavior is controlled by established routines and procedures.

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4

The Teacher and Problem Solving: Classroom Instruction

In the previous chapter we considered a series of behaviors of the teacher which are relevant to the development of problem-solving skill but which are essentially noninstructional in nature. Such management behaviors are directed toward constituting an environment in which instruction is likely to be productive. Theoretically, pupil learning will be retarded if the management aspects of teaching are not executed appropriately. The second principal function of teaching, of course, is an instructional one. This chapter is concerned with the nature of the relationships between the teacher's instructional behavior and the pupils' problem-solving performances.

INSTRUCTION, SET, AND RIGIDITY

Have you ever had the experience of trying to separate the pieces of a mechanical puzzle, only to find that you persist in attempting to pull them apart with force even though that behavior is unsuccessful? Such behavior is a simple example of what we typically refer to as stereotypy or rigidity in problem solving. Rigidity encompasses both the cases where a given behavior pattern is repeated although it is unsuccessful, and where it is used when a different, perhaps simpler response pattern would solve the problem more easily.

Some of the most interesting and provocative information about the relationship between set and rigidity in problem solving comes from a series of experiments reported by Luchins (1942). The general question Luchins sought to answer was of the form, "If you teach an individual a specific method for solving a problem, then allow him to solve a series of problems where that method is appropriate, what will happen to his behavior when he confronts problems which can be solved more directly than by the prescribed method?" Luchins was also interested in the potential effect on behavior of a warning to be alert. For most of his experiments he used "water jar problems" as experimental tasks. The subject is instructed that from three jars, A, B, and C, he is to get a specified amount of water. An illustrative problem is constructed so that the subject (hypothetically) fills jar B, then subtracts enough water to fill jar A once, and jar C twice. For example, the problem might read, "Jar A contains a 6-quart capacity, jar B contains a 128-quart capacity, and jar C contains a 1-quart capacity. Obtain 120 quarts of water." The formula $B - A - 2C$ is applicable. A series of problems, all solvable by the same method, then follows. After a half dozen or so problems, others are inserted which can be solved by the earlier learned formula, but for which a simpler method is applicable. For example, "$A = 15$, $B = 39$, $C = 3$; obtain 18." While 39 minus 21 will yield the required 18 quarts, the subject need only add A and C to reach the desired quantity. Frequently subjects, well-educated adults as well as elementary school children, fail to note the more direct solution and proceed with the $B - A - 2C$ formula.

To some subjects, Luchins provided a clue before the beginning of the experiment. This clue consisted of a reminder to write the words "Don't be blind!" on their answer sheets following the completion of the sixth problem. As indicated before, the first six problems usually were introduced to build up the set or to blind subjects to the fact that a change in procedure was coming. However, the "Don't be blind!" instruction tended to have differential effects, depending upon the subject's interpretation of its meaning. When the subject made the appropriate interpretation, that is, "Be alert now, I'm going to throw you a curve!" the set frequently was broken. Subjects scanned the array of jars for cues which would suggest an alternative means of attaining the solution. Other subjects, typically those with whom the instruction was ineffective, apparently thought it meant, "Don't be blind! The method I have taught you still works, even if the problems look different." Some subjects, under this instruction, proceeded to apply the B — A — 2C formula even to subsequent problems which were not solvable by the formula given.

A number of the experimental subjects used by Luchins in his investigation of the role of *Einstellung* or rigidity in problem solving were elementary school pupils. Luchins observed that the environment to which pupils had become accustomed in the classroom was instrumental in influencing their responses to the water jar problems. Particularly prone to the *Einstellung* effect were the pupils of teachers who stressed classroom routine and drill. Postexperimental reactions of such pupils included expressions of surprise or indignation that a teacher (the experimenter) would expect pupils to use a different method to solve problems than the one which he had explicitly taught them.

It seems reasonable to extrapolate two principles of practice for the classroom from Luchins' findings, although there is not specific evidence currently available to support them.

1. If pupil problem-solving behavior is to avoid the inhibiting effects of stereotypy, the classroom atmosphere must reinforce (or at least must allow) attempts to vary strategy in seeking solutions. (The reader may wish to review the section on environment in Chapter 3.)

2. When the teacher provides series of problems, even though these are primarily intended to furnish practice on a recently taught principle or operation, it seems advisable to insert an occasional problem which demands the application of a different principle. The value of practice is questionable if the pupil knows from previous occasions that tomorrow's homework is invariably based on today's lesson.

Conversely, if pupils are aware that problems are likely to demand a variety of applications, including recently as well as earlier learned operations, there should be an additional value beyond merely breaking down response rigidity. Such foreknowledge might also be expected to induce pupils to analyze problems carefully inasmuch as they cannot rely upon correspondence with recent teaching. The discussion of problem solving as transfer of training in the next chapter will give us an opportunity to reexamine this topic in an altered context.

A study by Miller (1957) furnishes at least indirect support for our contentions. Miller tested a group of 120 boys in a British secondary school which included both "modern" and "technical" streams. The boys in the "modern" stream complete their formal education at the secondary school level, while most of the boys in the "technical" stream are headed toward advanced training. Apparently there are quite different expectations held by the teachers for classes in the two streams. The same teachers in this school instruct classes from both streams, but they report that they employ different instructional techniques. Drill procedures are, according to the teachers' statements, used more extensively with classes from the "modern" stream than with those in the "technical" stream.

Since Miller was interested in determining whether there are relationships between intelligence and rigidity, and between rigidity and teaching methods, he administered the Luchins water jar problems to boys in both streams of the school. He then computed a rank-order correlation between their scores on the water jar problems (a measure of rigidity) and intelligence. This yielded a negative but significant relationship (rho = —.304). A negative correlation indicates that the two factors under examination vary with each other, but one decreases as the other increases. In this case, the negative correlation suggests that the higher a pupil's measured IQ, the lower his score on rigidity is likely to be.

Miller also attempted to answer the question: Is rigidity related to the type of instruction pupils receive in school? This seems to be an interesting and important question, and it is unfortunate that Miller's answer to it is not definitive. He selected students from the middle IQ range of both streams so that there was no significant difference in intelligence between the two groups. This gave him a sample of twenty-nine boys from the modern stream with a mean IQ of 100.6, and a group of forty-one technical stream boys with a mean intelligence test score of 102.8. When these two groups are compared with respect to their rigidity, the differences are quite dramatic. Of the boys from the modern stream, 83 per cent were high on *Einstellung*, whereas only 49 per cent of the boys in the technical stream had high rigidity scores.

Miller argues on the basis of these data that, since the boys all shared the same general school environment, and the groups were of equal intelligence, the differences in rigidity must be accounted for by some additional factor or factors. He suggests that, although the boys are in contact in their classes with essentially the same group of teachers, the teachers report that they handle the classes differently. His interpretation is a long way from providing evidence that routine drill methods of teaching contribute to the development of rigidity in pupils, but it does raise the possibility that teaching methods may be more important in the development of *Einstellung* than has been thought in the past.

Luchins' comments about the reactions of pupils in classes where instructional procedures are highly routinized are no more definitive than Miller's supposition. The two independent reports placed together, however, do suggest a trend. Until further evidence is available on the point, it seems reasonable to hypothesize that methods of teaching and rigidity are related to each other.

EFFECTS OF TRAINING PUPILS IN ALTERNATIVE METHODS OF SOLVING PROBLEMS

The teacher's goal in the development of problem-solving skill is broader than teaching pupils to solve any given set of problems successfully. He must also be concerned with developing flexible but usable strategies that enable pupils to attack problems independently, that is, when cues ordinarily available from the context of the lesson or from the teacher's guidance are missing.

Ackerman and Levin (1958) attempted to train elementary school children not to form a set in problem solving or to abandon it once it becomes evident that the mode of attack they are using is not going to be successful. The investigators divided their sample of sixth-grade pupils into two groups, an alternative group (A) which was taught two methods by which to solve a set of training problems, and a no-alternative group (NA), which was taught only one method for solving the same set of problems. The items in the training series were the familiar Luchins water jar problems, modified so that they were susceptible to solution by either of the methods in which the A group received instruction. Ackerman and Levin were interested in the effect which the alternative method of training would have on pupils' behavior when they encountered new problems which would not yield to either of the methods previously practiced. A transfer test was also given to both groups of pupils. This test consisted of a set of problems different from the Luchins water jar items. For both of the tests following the training session, the results were essentially the same. No statistically significant differences occurred between the A group and the NA group in the total number of problems solved correctly. However, the difference between the two groups was in the direction predicted, that is, the A subjects did solve more problems than the NA subjects. Despite the failure of the training in alternative methods of solution to yield significant differences in total solutions, other important differences between the two groups appeared. Members of the group trained with alternative solutions were more variable in choosing alternative methods of working on the problems than were the members of the NA training group. Also, the A pupils persisted in working on the problems for longer periods of time than the NA subjects.

The interpretation of Ackerman and Levin's findings for classroom practice is complicated by their failure to report significant differences in the total number of correct solutions between the pupils in the two training conditions. Obviously, if we knew that there was a direct correspondence between an instructional method which concentrated on exposing pupils to multiple approaches to problems and the number of problems pupils could subsequently solve, we could feel relatively certain about the wisdom of incorporating such methods into the practice of teaching.

The training period the pupils experienced in this experiment was relatively brief; the problems with which they were dealing were highly proscribed. It may be that, as a consistent practice in the classroom, careful training in selecting alternative ways of seeking solutions to problems will result in the kind of increment in solutions which Ackerman and Levin were hopeful of demonstrating.

EFFECTS OF VARIOUS KINDS OF INFORMATION

This section is concerned with the relationship between the kind and amount of information supplied to the pupil involved in problem solving and his problem-solving behavior. The fundamental question to be asked here pertains to the consequences for pupil problem solving of variations in the guidance, instruction, or direction that the teacher provides.

Suppose, for example, that an arithmetic teacher wants her class to learn the Odd Number Rule (the sum of a series of n odd numbers in sequence, and beginning with 1, is equal to n^2), but to learn it in such a way as to maximize the likelihood both that it will be remembered and will be used under appropriate circumstances. How shall the teacher proceed?

Variations in instruction provided by investigators of this question can be roughly separated into three conditions: (1) complete guidance, in which the principle and its applications are presented; (2) partial guidance, the particulars of which vary from study to study, but in which experimental subjects are given some information about the rule; and (3) no guidance, in which subjects are to discover or induce the generalization from examples.

Hendrix (1947), in a frequently cited study, reported that subjects who discovered the rule but did not immediately formulate it (method of unverbalized awareness) took greater advantage of opportunities to apply the rule than subjects who discovered the rule and verbalized it, or subjects who were first given the rule, and then practiced its use with various examples. On the strength of these findings, Hendrix suggests that pupils' ability to transfer or apply a generalization from the context in which it is originally learned to a new one will not be materially improved by first specifying the principle and that, in fact, such verbalization may impede the desired use of the principle. This is a startling recommendation, but examination of Hendrix' results casts great doubt upon the reliability of her findings. She replicated her methods on three separate but small samples (a total experimental sample of 40 persons). Each time the results were the same, that is, more applications were made by the unverbalized awareness subjects. However, the differences among her subjects, while always in the direction predicted, are not statistically significant. In fact, the difference between the unverbalized awareness subjects and those who verbalized the rule as part of their experimental treatment is so small as to occur by chance about one time in three.

Kersh (1958) explained the superiority of a discovery method in problem solving, not in terms of learning *per se*, but as a consequence of an increment in motivation which appears to lead to increased independent practice on the task. In a subsequent study (Kersh, 1962), designed to examine differences in retention and transfer of principles between a directed group and a discovery group, Kersh employed a control group which was given the principle to be learned and a series of examples to which it was to be applied. When transfer tests were administered to all subjects over periods ranging from three days to six weeks, the major finding was one totally unanticipated by the investigator. The control group, which had memorized the principles and practiced their application, was better able than either the directed or the discovery group to use the principles to solve new problems and to state the substance of the principles. This is a significant result, not only in its implications for the teacher's role in guiding problem-solving behavior, but also because of what it suggests about the utilization of instructional time.

By no means do we intend to raise the ghost of the economy of time issue. Hopefully, we have progressed beyond the point where every classroom activity must be evaluated in terms of its utilitarian function. Nonetheless, instructional time is at a premium. It is difficult to defend the discovery method, which is usually extremely time consuming, when confronted with data like those Kersh has presented. Other investigators have typically reported that some assistance to experimental subjects, either in the form of information bearing upon the method of solution to be used or of the applicable principle, yields results substantially superior to an unstructured problem situation in which the pupil is forced to search for a solution without the assistance either of organized materials or some verbal guidance from the teacher or experimenter.

Ausubel (1963) has written a careful and eloquent rebuttal to the proponents of learning by discovery. He argues that reception learning—learning which occurs when factual material is presented to the pupil in an organized way, as through texts, lectures, or films—when appropriately directed, possesses meaning for the pupil and avoids most of the disadvantages of the process of discovery. The chief elements in his discussion of this topic are summarized below.

1. From the standpoint of time-cost, discovery methods are uneconomical and inefficient.

2. It is extremely difficult to present large amounts of subject matter in any systematic fashion through the use of discovery methods. Ausubel contends that real understanding of a discipline by a pupil depends upon his knowledge of its structure (the generalizations upon which a field is built and the relationships among such generalizations). Such understanding is not well or readily developed by discovery methods which tend to highlight one usually small and isolable element of subject matter to the exclusion of others of equal significance. In effect, discovery methods are not favorably adapted to the systematic presentation of knowledge.

3. Unstructured manipulative behavior may be unproductive, both in the sense of wasting time and adding little if any to the pupils' store of usable knowledge. Ausubel uses the somewhat dubious illustration of a pupil immersed in a tubful of water engaging in a variety of aimless behavior without ever seeing a relationship between his immersion and the volume of water displaced.

Corman (1957) conducted an experiment with a group of senior high school students in which he examined the influence of providing different amounts of information about principles or methods for solving problems on the success the pupils enjoyed. The general hypothesis that Corman tested was that guidance in problem solving, to be effective, must be highly related to the task. More explicitly he predicted that when the criterion is the solution of a problem, guidance about the method to use in attaining solution would be of help, and that when the criterion is not solution itself, but stating the rule to be used in solution, guidance relevant to the rule would facilitate such verbalization.

The task used by Corman was in the form of a puzzle. The subjects were confronted with 5 adjacent squares composed of a total of 15 matches. By moving only 3 of the matches, they were to reduce the number of squares to 4. Several limitations were placed upon the way in which these changes could occur. For example, matches could not be stood on end; only 1 match could serve as the side of a square, and all the squares were to be of the same size, 1 match length.

Subjects of this experiment were 233 twelfth graders from selected suburban New York and New Jersey high schools. The total sample was divided into high ability and low ability groups. Pupils who scored above the median on a group-administered intelligence test were identified as high ability; those who fell below the median were designated as low ability. Each subject was provided with some information about the method for solving the problems and about the rule to use in arriving at solutions. For the rule or principle, three degrees of information were provided: (1) no information, (2) some information—there is a rule which will be of use in solving the problems, and (3) much information—every match should be the side of only one square. Three similar kinds of information were provided with respect to the method to be used in solving the problems: (1) no information, (2) some information—subjects were directed to shade certain squares of the test problem, and (3) much information—the subjects were told which matches to move and to practice these moves.

A total of nine combinations of guidance were used, varying from the case where the subjects were given no information about either the principle or the method to the case where subjects were given complete information about both rule and method.

The experiment itself consisted of having subjects solve three guided problems called the instructional problems. These were followed by three simple transfer tasks and five complex transfer tasks. Complexity was defined in terms of the similarity of the transfer problem to the instruction problem. Thus the simple transfer tasks were more similar to the instruction problems, the complex tasks were more remote.

The subjects' final task was to write the rule they had used in solving the problems.

Corman had hypothesized that pupils of lower and higher mental ability would not profit differentially from the several kinds of guidance, that is, that the type of guidance which was helpful to high ability students would also be effective with pupils of lower mental ability. His results did not support that hypothesis. Therefore, it is necessary to consider the results separately for the two subsamples.

If we consider first the results for the above average pupils, we find that information about the rule was of no help in solving the instructional problems, that is, when these pupils were given no information about the method to use in solving the problem, whatever amount of information they were given about the rule did not change the frequency with which the instructional problems were solved. Pupils who were given some information about the method performed more adequately on the instructional problems, and, as might be expected from what has been stated earlier, the greatest facilitation occurred for pupils who were given maximum information about the method.

For the simple transfer tasks, two combinations yielded results superior to the other seven combinations. Pupils did best in solving the simple transfer tasks either when they were (1) given maximum rule information and intermediate guidance about the method or (2) when these conditions were reversed, when the pupils were given some information about the rule and maximum method information.

For the complex transfer tasks, those pupils who were given information only about the method or intermediate information about the rule only fared best. At first glance these findings are difficult to integrate with those about the instruction problems and the simple transfer problems. However, the complex transfer tasks were different from the other tasks in many specifics. It may be that a great deal of information about the rule and method which were useful for the solution of the earlier simple problems resulted in negative transfer, or interference, with the more complex problems, whereas the intermediate conditions, either for the rule or for the method, provided the pupil with an entering wedge, a way to make an intelligent attack on the problems without arbitrarily committing himself to a plan of action which was not totally suitable for solving the new problems.

When the results are examined for the other half of the experimental sample, the pupils whom Corman identified as low in ability, the most obvious finding is that information about the rule, in any amount, was of no assistance to the pupils in solving any of the tasks. The low ability pupils performed best when they were given either intermediate or maximum amounts of information about the specifics of the method to use.

Corman employed two kinds of dependent variables. The first, success in solving three kinds of problems, we have already discussed. His other interest lay in observing which of the pupils would be most successful in learning the rule. The result is straightforward: the more information the pupil had been given about the rule, the better he was able to write it. This result was significantly different, however, only for the comparison between pupils who were given maximum information about the rule and those who were given no information about it. Although subjects who had been provided with intermediate information did some better than the "no information" group, the difference between them was not significant.

It is possible to place the results of Corman's investigation in a broader context of research results and educational practice. Ordinarily, less talented pupils require more direct, concrete experience with learning materials than do above average or gifted students. Corman's finding that his low ability pupils performed best under the conditions where they were given information about the method to use in solving problems, and that no amount of information about the rule to apply appreciably altered the level of their performance, would seem to fit this generalization. The more able pupils in Corman's sample also profited from information about method, but for the transfer problems, rule guidance, either in combination with information about the method or by itself was equally efficacious.

Corman's other findings, that success in learning to write the rule was dependent upon the amount of information provided about the rule and that success in solving the problems and in writing the rule were independent of each other are evidence that the two kinds of tasks did not transfer to each other. Carpenter (1954) reported similar findings in an experimental study of concept learning. His subjects were to learn a functional block-sorting concept, that is, they were to learn to place certain blocks in one stack, others in a different stack, and so forth, based upon certain attributes of the blocks. While most of his subjects learned to do this task, only one fourth of them were able to give a verbal statement of the principles they used in discriminating one kind of block from another.

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5

The Evaluation of Problem-Solving Skill: A Matter of Transfer

OUR SCHOOL SYSTEMS' existence depends heavily upon assumptions about transfer of training. We assume that what children learn in the classroom today will facilitate their learning tomorrow or next week. The skills and attitudes learned in the early years of the elementary school are fundamental to successful performance in later school years and in adult life. In one sense most of the activities of the school are justified because what they teach the child is expected to be somehow useful to him either immediately or in the future. Usefulness is, of course, a difficult word to define. Narrowly construed, it can impose a limited, vocational emphasis upon the purposes of the school. Most educators would agree that the usefulness of school learning is to be defined in terms of intellectual and esthetic values as well as in terms of what is immediately practical.

The teacher of reading, whether at the elementary or secondary school level, is naturally concerned with developing skills in word analysis, vocabulary development, and other skills which can be thought of as contributing to the mechanics of reading. His concern is equally great, however, that pupils learn to interpret literature, that they understand the differences between reporting and editorializing and develop other skills which contribute to their ability to read critically. The argument is easily made that skill in critical reading is essential for citizens of a modern society, and the assumption is made that training in the school on such skills will transfer to out-of-school situations.

In light of the above discussion, our attention is directed to two related questions: How does transfer of training occur? How should one teach in order to promote transfer?

GENERAL NATURE OF TRANSFER

Transfer of training refers to the extent to which something learned in the past influences the course of future learning. If a student is able to master college algebra more easily after he has studied algebra in the secondary school than would be the case if he had no earlier training in the subject, we can say that his initial learning transfers positively to his later learning of algebra. Our everyday lives, in and out of school, are replete with instances of such positive transfer. A person who already has a relatively good knowledge of French, for example, will learn Spanish with less difficulty than a novice linguist. This may occur for several reasons: French and Spanish are both Romance languages with similar structures and with some cognates. In addition, however, the French student has learned some general principles about the study of languages. He has previously had experience in learning foreign vocabulary, in striving to "think" in the new language, and so forth. These techniques stand him in good stead when he turns his attention to the mastery of a new but similar study.

In the same vein, a stenographer who has learned to type on a manual machine does not have to relearn all her skills when the office buys her a new electric typewriter. There is great positive transfer from one situation to the other. An individual who has learned to drive an automobile finds only minor difficulty in driving one car as opposed to another. Again, there is considerable positive transfer of his general skill in driving.

However, transfer is not always positive. Consider our typist again. The pressure of strokes required for a clear imprint on her manual typewriter are now much too hard for the electric machine. From time to time she depresses keys on the new typewriter without intending to, and some time and experience are required before errors of this sort are eliminated. More negative transfer occurs if the position of keys is different. If initial learning has taught that the quotation mark is the first key in the top row, many trials may be necessary before the typist learns its new position. The driver who has for years driven an automobile with a manual transmission encounters similar negative transfer when he purchases a new car with an automatic transmission. A period of adaptation is required before his left foot stops depressing a clutch that is not there. Or, if he has learned to drive in England or Sweden he may have trouble in the U.S.

For many years before the opening of the twentieth century, educators and psychologists held views about the nature of transfer of training that were rather simple and straightforward but definite. The purpose in having students study classical languages or mathematics was only partly for the sake of the knowledge of the study itself. The place of studies in the curriculum was justified largely on the basis of their value as "mental disciplines."

During the nineteenth century, faculty psychology exerted powerful influence on our thinking about education. According to faculty psychology the mind was composed of a number of specific "faculties" which, when properly trained, were of general use. For example, the study of mathematics was believed to improve the faculty of reasoning. Thus, a student gained not only a knowledge of mathematics from his study, but improved his power of ability to reason on any topic where reasoning is important. At the elementary level, pupils were required to memorize their textbooks, partly because of the value of their maxims, but also because practice in memorizing improved the memory faculty; thus, constant practice in memorizing poetry left one better able to remember information of any nature.

Shortly after the turn of the century a series of studies of transfer of training were reported which were to occupy the attention of educational psychologists interested in mental discipline and transfer for the next quarter of a century. Thorndike and Woodworth (1901) challenged the claims made in the name of formal discipline. They undertook an examination of the effects of training in one mental function on others. For example, one of the tasks they administered to subjects consisted of extensive practice in estimating the length of short lines which varied within a narrow range. Following such practice, the subjects were asked to estimate the length of a series of longer lines. Thorndike and Woodworth argued that if the powers of discrimination were susceptible to general improvement, the subjects should do about as well at estimating the longer lines without practice in so doing as they had done with the shorter lines after much practice. When transfer in this function, together with most of the others which they examined, failed to occur as predicted, Thorndike and Woodworth pointed out the absence of general transfer and began to question the value of mental discipline.

A spate of investigations of this order followed during the ensuing years. For the most part they supported the findings of the original Woodworth and Thorndike studies. However, virtually overlooked in these reports was the fact that some transfer did, in fact, occur. Sleight (1911), for example, discovered that children who had practiced memorizing poetry learned nonsense syllables more readily than a control group who had spent the earlier period working arithmetic problems which did not demand memorizing. At the same time, other children who had spent the first period learning the substance of prose materials experienced more trouble in memorizing the nonsense syllables than the group that had memorized poetry. It appears that what led to improved learning of nonsense syllables was not the mere fact of having practiced memorizing, but that the mode or technique of memorizing poetry is also useful when the task is learning nonsense syllables.

Thorndike conceded that transfer occurs from one task to another, but what he disputed was that transfer is complete or that it occurs automatically. He formulated a theory of transfer which was heavily based upon his earlier studies with Woodworth. This formulation was the "theory of identical elements," in which Thorndike hypothesized that if task B is learned more easily after task A has been learned, it is because the two tasks share common elements. B is learned in less time or with fewer errors because it is already partly learned through studying A. It is interesting to note in this connection that Thorndike theorized that these identities may be either in the content or the substance of the two tasks or they may be in the procedures (Thorndike, 1913).

Since Thorndike's day the investigation of the conditions conducive to transfer of training has defined a major interest of experimental psychologists. Studies of transfer are usually designed so that the psychologist will be able to infer from his results whether the experimental conditions under which his subjects learned one task facilitated their learning of another task, interfered with learning, or had no effect on the learning of another task. Facilitation and interference are simply other terms for referring to what we previously called positive and negative transfer.

The psychologist is ordinarily concerned about the sequence of events in his investigations of transfer of training. While we might usually think of transfer occurring from an initial task to one learned later, it is also true that later learning may transfer to the performance or the recall of the initially learned task. Studies of the first kind deal with *proaction;* those of the second, with *retroaction.* The psychologist might wonder whether vocabulary drill contributes to reading comprehension. To answer this question, he could select a group of children of the age or educational level about which he wishes to be able to generalize, test their reading comprehension, then give them training for a period of time in activities which he can reasonably define as practice or drill in learning vocabulary. After this training period the reading of the subjects would be tested again to see if any improvement had taken place. If the pupils are better able to comprehend the ideas in these passages after the vocabulary drill than they were before, the inference is drawn that proactive facilitation has resulted from the vocabulary training to the ability to comprehend reading material.

The psychologist might be interested in speed of reading as well as in pupils' ability to comprehend meaning. Perhaps he has hypothesized that teaching pupils word analysis skills (breaking words into their components as an aid to sounding out new or unfamiliar terms) is likely to slow down their reading rate. He would begin by selecting a group of pupils with whom to experiment and testing their initial reading rates. They would then be trained in the new word attack skills, and their rate of reading material would be measured again. If the second measure of speed was lower than the first, it would suggest that retroactive inhibition or interference had occurred, that is, that learning skills to sound out words slows down the pace of reading.

The experimental task in transfer designs is known as the interpolated activity. For instance, in the first hypothetical study described above the drill on vocabulary words is an interpolated activity. The interpolated material in the second study is the training in word analysis skills.

Of course, the conduct of experiments in transfer is not as simple and straightforward as we have pictured it to be. The experimenter would have to be at great pains to relate the type of vocabulary instruction, for instance, to reading comprehension. Similarly, he would be obligated to explain, insofar as he is able to, what it is about the study of word analysis that interferes with pupils' rate of reading. Concern for the generalizability of his findings imposes great demands on the experimenter for the construction or selection of his experimental tasks and measures. By the same token he must be able to provide assurances that it is the treatment he has used and not some other experience his subjects are undergoing concurrently that results in the gains or losses in performance which he reports.

Suppose, for instance, that in the first study we described that the experimenter tested the reading comprehension of several classes of third-grade pupils at the opening of school in September. He then conducted special classes in vocabulary work with these pupils several times a week until the following February, at which time he again tested their reading comprehension. It would not then be very surprising to find that these children have improved substantially in their performance on the second administration of the test of reading comprehension. Many forces have been in operation during the five months which elapsed between the two tests in addition to the one to which the experimenter wishes to attribute the change in reading comprehension. For one thing, the pupils are more mature in February than they were in September; this has implications for their improved ability to comprehend independently of any instruction. In addition, they have experienced another full semester of instruction in school, including but not restricted to the reading program itself. Apart from the school curriculum, the children have had opportunities to read recreational and informational books supplied by the library and the home, and they have perhaps profited from many sources in the family and the community at large which the investigator is unable to specify.

Left in its present condition, the experimenter's finding is simply uninterpretable. It may be that all, that some, or that none of the September to February gain in comprehension is the result of the special training he provided. It is unlikely, but not inconceivable, that the vocabulary development program actually interfered with the pupils' ability to comprehend written material, and that this decrement had to be overcome by the gains accruing from the children's other experiences in reading during the experimental semester. It is to avoid difficulties in interpretation of this sort that scientists employ control conditions or control subjects in experiments. In the present case the psychologist would have selected another group of pupils as much like his experimental pupils as possible in reading comprehension, in intelligence, and in the kinds of homes and schools from which they came. He would, in short, have attempted to say that the two groups of pupils resembled each other very closely before the experiment, and that during the experimental period, except for the training given to the first group, their experiences could be expected to be very similar. Whatever differences then resulted in reading comprehension between the two groups on the February test of comprehension could more reliably be attributed to the special training in vocabulary.

The Transfer of Principles and Methods

In the first section of this chapter we addressed our attention to some of the general considerations about the nature of transfer. We examined several theories about transfer that have been in vogue in education or in psychology for some time during the last seventy or so years. We learned that these theories have varied from one which predicted automatic and almost total transfer from one area of study to another, to one which promised very little transfer apart from the elements of one performance that are common to another. But to this point we have not paid much attention to the fact that transfer of principles and of generalized methods or procedures also can occur.

Teachers provide instruction in the hope and expectation that what their pupils learn will have applicability to future situations in which explicit instruction is not available. It is not difficult to enumerate examples of such transfer which teachers take for granted, not necessarily realizing that they are instances of transfer of training. The primary grade child, for example, who has learned that the sum of two plus three is identical with the sum of three plus two, and that the sum of four plus five is equal to the sum of five plus four, will not need to examine every possible combination of addends before he is able with certainty to add numbers in the order in which they are arranged. There is a mathematical rule which governs such operations, but the pupil need not be able to state the rule in any formal sense to be able to use it. Similarly, the mathematics teacher who is at pains to teach his pupils generalized procedures for attacking and solving word problems in algebra expects that such training will apply to a broader range of tasks than that with which the training concerns itself.

The evidence on this question of general or nonspecific transfer comes from a variety of sources and has a long history, reckoned by the time in which topics in educational psychology are measured. Probably the most frequently cited investigation is one reported by Judd (1908). Judd engaged a group of fifth- and sixth-grade boys in throwing darts at an underwater target. He gave some of the boys instruction in the principle of refraction, but he did not give this information to the others. Judd reported that whether the boys knew about refraction or not made relatively little difference in their ability to hit the underwater target. After some practice at this task, the target was moved to a different depth. Then, according to Judd's account, the pupils who had been taught the principle of light refraction succeeded better than those who had no such special instruction.

From Judd's description it appears that knowledge of the general principle to be applied would make little difference in the acquisition of a skill, but that, once the skill has been learned, knowledge of the principle reduces errors in performance. There are a number of difficulties associated with Judd's experiment as it has been reported. For one thing, no careful statistical measures were employed, and we do not know with much certainty how reliable the difference was between his instructed and uninstructed groups. Furthermore, the boys were throwing darts at a target in a tank of water, which raises some serious questions about the accuracy of his findings. Although an instructed boy might very well understand where he needed to aim his dart in order to strike the target, while an uninstructed boy would aim directly at the image of the target in the water, random errors associated with differences in motor skill and with the unpredictable skidding of the dart as it penetrated the water might have been more influential determinants of success than knowledge of the principle itself.

In 1941 a pair of investigators conducted an interesting attempt to replicate Judd's earlier study. Hendrickson and Schroeder modified the task so that the boys in their experiment fired BB's from an air rifle at a submerged rifle target. They had demonstrated that at the distance the boys had to shoot, errors in aiming the rifle played a very minor part in determining where the pellet struck. Thus, if instruction in the principle of refraction does make a difference in where the boys expect the target to be, this difference should be reflected in the results.

They employed 90 eighth-grade boys in their experiment, thirty each in a control condition, in Experimental Group A, and in Experimental Group B. The boys were to fire first at a target submerged 6 inches and later at a target which was only 2 inches beneath the surface of the water. A record was kept for each boy, at each depth, of the number of shots required before he hit the target three times in succession. The boys shot from a platform raised 18 inches above the floor and from a distance of 8 feet. The angle of incidence between their line of vision and the water's surface was 51 degrees. The apparent displacement of the target at 6 inches was 3.11 inches, and at 2 inches, the displacement was 1.04 inches.

The members of the control group were given no formal instruction except that they were to try to hit the target. Members of Experimental Group A were given an explanation of the principle of refraction together with a diagram showing that an object beneath the water is not at the place where it appears to be. Control Group B subjects were given the same instruction as the other experimental subjects, plus the information that the deeper the water, the farther the object will be from its image.

At a depth of 6 inches, the control subjects required the most shots to hit the target the required number of times; the A experimental subjects needed more shots than the B subjects. Although these differences were in the order predicted by Hendrickson and Schroeder, they were not statistically significant. Hendrickson and Schroeder argue that their findings for the initial trial are different from those reported by Judd, who said that knowledge of the principle of refraction was not of consequence for the first series of shots. In the absence of statistical significance their interpretation is difficult to accept, despite the fact that the order of mean numbers of trials was as they had predicted.

On the transfer test the target was raised 4 inches. Again, the order of performance was as Hendrickson and Schroeder predicted, with the control subjects requiring the greatest number of trials and the subjects who had received the fuller explanation of refraction requiring the fewest number of shots. However, the only difference we would today interpret as significant was that between the control subjects and the group B experimental subjects. It is also noteworthy that the boys in all three of the groups improved markedly in hitting the target at a depth of 2 inches. For each of the three conditions, subjects required slightly more than three trials fewer to strike the 2-inch target than they had needed at 6 inches.

The experimenters observed that once the boys saw the principle involved, that is, the necessity of aiming to the side of the target rather than directly at it, they were immediately able to strike it three times in succession (and presumably could have hit it indefinitely if requested to do so). As the data suggest, it was not only the boys in one of the experimental groups who experienced such insight or sudden understanding of the requirements of the task, control subjects as well improved their performances as they began to see the discrepancy between image and object. The preexperimental instruction appears to have shortened the time and the number of trials necessary for subjects to alter their behavior appropriately, but the absence of such instruction by no means precluded the possibility of improvement by the control subjects.

While the paper by Hendrickson and Schroeder provides useful data about the transferability of a general principle, it leaves unanswered or only partially answered a number of questions about transfer in problem solving which are of considerable significance to classroom teachers. At this point we shall try to indicate the nature of these questions and sketch some of the possible implications for teaching. In the concluding section of this chapter we shall return to them as we try to elucidate a series of principles germane to teaching for transfer.

1. The results of the study are ambiguous, which forces any clear-cut interpretations of the findings to be tenuous. By ambiguity in this case we have reference to the fact that a reliable difference occurred for only one comparison: that between the control subjects and the Experimental Group B subjects on the transfer task. It seems that knowledge of the general principle (supplied to Experimental Group A) was not sufficient to improve performance markedly over that of the boys who were given no special instruction. The addition of an extension of that principle (the information that the deeper the water, the more distant the object from its image) did yield a significant reduction in the trials needed, but only when compared with the performance of the uninstructed subjects. The added information probably yielded more specificity about the demands of the task when the depth of the target was changed, since the instructed boys could reason that the higher the target was situated in the water, the closer the object and image would be. The additional information may have played another part. It may have heightened the likelihood that the boys would comprehend and act upon the applicability of the principle to the job at hand. If that is so, it may not be the substance of the additional information which was instrumental in improving their performance, but the fact that employing the principle would probably yield positive results.

2. What did the students learn about the general principle? Presumably, all the experimental subjects learned the principle of light refraction. At least they were exposed to an explanation of it. Although the control subjects did reach the learning criterion, there is no evidence that they learned the principle as well. Corman's (1957) subjects, in the monograph reviewed in the last chapter, were able to state the rule for solving the

problems only if learning the rule was part of their training. Our best guess is that the control subjects in Hendrickson and Schroeder's investigation would have considerably less success in verbalizing the principle than would members of either of the experimental groups. Knowledge of the principle in itself may seem to be relatively inconsequential, but it may have an important bearing upon performance when the specifics of the task are altered, or when a longer interval of time intrudes between initial acquisition of the skill and the transfer test.

3. Why did the control subjects improve their performance on the transfer task? The conditions of this experiment seem to have been especially conducive to improvement in performance by control members. Although they were given no explicit instruction about where to aim their shots, or the effect of submersion upon the bending of light rays, they did receive immediate feedback about the adequacy of their performance, that is, the subject could see whether his shot struck the target or not. This feedback gave him at least some information about whether to change his aim and, in some cases, how it should be changed. This was true for the experimental subjects as well as the control subjects, of course, but it is probably the best explanation of the improvement of the control pupils' performance.

Pupils are frequently involved in classroom problem solving that does not admit of feedback as carefully controlled as in the case under discussion. If feedback had been less readily available to subjects in Hendrickson and Schroeder's study, it would not be unreasonable to anticipate that the improvements registered by the experimental subjects in both groups would have been markedly better than those of the control subjects. In other words, the application of a principle to unfamiliar problems in the classroom may be more easily accomplished if the pupils have prior knowledge of the principle and are alerted to the possibilities of its use in solving new problems. We would expect this to be true particularly when the administration of moment-to-moment knowledge of results is difficult or impossible, for example, when there is no opportunity for the pupil to apply internal checks on the accuracy of intermediate stages of problem solving or when he will not receive knowledge about his performance until some later time.

FACILITATING TRANSFER OF PROBLEM-SOLVING SKILLS

A persistent problem in the literature on transfer of training in problem solving is whether individuals solve new problems more easily if they induce the applicable principle for themselves during the training series or are provided with the principle while they are learning to apply it. The results of studies that have examined such questions frankly are conflicting. Some investigators have reported that subjects perform best if given the principle; some do best under "discovery" conditions; others report that subjects who were given some assistance in discovering the principle solve transfer problems better than those who were given no help or those who were given the principle. Part of the conflict seems to stem from the different ways in which investigators have defined their experimental variables, but some of the difficulty seems to lie also in the logic of the interpretation of the findings. A recent paper will illuminate these issues and provide us with the background for discussion of classroom procedures when the teacher is interested in maximizing the ability of his pupils to use a general principle effectively in solving new problems.

Haselrud and Meyer (1958) hypothesized that greater positive transfer would occur if subjects were forced to induce a principle for themselves from concrete instances than if they were provided with a statement of the principle, which they were then to apply. To test this hypothesis they used an experimental group of seventy-six college students and a control group of twenty-four. The experimental subjects worked on two tasks, both of which were problems in learning codes. The first task consisted of a list of twenty sentences written in English. Each sentence was followed by its code translation. Above half the code sentences, a statement of the key to the code appeared. No such statement was given for the other sentences. The statements appeared above alternate sentences in the task. The control subjects did not work on the first task.

Both groups then attempted the transfer task, which was administered a week after the training series. Again twenty sentences were given, and each was followed by four possible translations. The subjects were to check the correct translation. This study used what we have earlier called a proactive design. Since the control group did not have an opportunity to work on the first lesson, any difference between their scores and those of the experimental subjects could be attributed to the influence of the first task. Since the mean score on Test 2 was significantly greater for the experimental subjects than for the control subjects, it was concluded that practice in translating English sentences into code does transfer to a similar task.

However, the principal interest of the investigators lay in determining whether a difference in transferability occurred between the two conditions under which the experimental subjects had been trained. Four scores were computed for the experimental subjects (1) the number of correct translations on the guided exercises of Test 1, (2) the number of correct translations on the unguided translations Test 1, (3) the number of translations correct on Test 2 which were like the guided examples of Test 1, and (4) the number of translations correctly completed on Test 2 which were like the unguided examples of Test 1. This made it possible to compare the effect of each training condition upon the subject's ability to translate the sentences in the second task.

Significant transfer occurred for both training conditions. The per cent of increase was greater from Task 1 to Task 2 for the unguided examples (46 per cent to 10 per cent for the guided examples). The investigators interpret this difference to provide support for their hypothesis. While at first glance this seems to be a reasonable enough interpretation, it leaves at least one important question unanswered. The subjects solved more of the code problems on the first task when they were given the principle than when they were not. Although the *proportion* of correct choices made on Task 2, which were based on codes like those for which the subject was given no guidance on the preliminary task, is significantly greater, there is no difference on the transfer task in the total number of correct solutions. When we look at the number of correct solutions on the second task of problems like the guided examples of Task 1, and compare this number with the correct solutions on Task 2 based on the unguided examples of Task 1, no difference is apparent. Haselrud and Meyer's interpretation needs to be qualified by asking what question about transfer of a principle is it that teachers are likely to want answered. If that question is simply "Which method leads to maximum transfer?" the answer seems to be: "Any method which allows pupils an opportunity to practice using the principle. Whether the pupil is given the principle or forced to induce it during practice makes little difference if the criterion is the number of problems he can solve on a transfer test." On the other hand, if the teacher is also interested in the conditions under which pupils are likely to perform in a superior way on the practice material as well as on a transfer task, the results seem to favor a method of guided practice, since the sentences on Task 1 which provided the principle were more frequently solved than those which did not. It may very well be, of course, that if the subjects had practiced with the unguided sentences until they were as successful as with the guided ones, a significant difference in transfer would have resulted. Unfortunately, Haselrud and Meyer did not design their study in a way that sheds much light on this speculation. At any rate, the teacher would have to consider whether the additional time in training on principle induction would be warranted by the possible gain in transfer since, presumably, equal additional time spent on practicing the application of the principle would also facilitate transfer.

Teachers usually find that the amount of time to be devoted to practice in problem solving is limited. Within this limitation, when a method of problem solving is to be learned, how should the practice time be distributed with reference to the types of problems to be practiced? One might guess that the more different problems pupils practice which are generically the same, the more transferable the method would be to later problem solving. Evidence on this point is found in an experimental study by Morrisett and Hovland (1959). The investigators predicted that subjects would produce better transfer scores if they were trained on a limited number of practice problems of different kinds than if they trained only on one such problem or on a wide range of different problems. They also predicted that subjects who practiced repeatedly on a single problem would secure better transfer than those who worked on a broad variety of problems.

With high school students as subjects, Morrisett and Hovland trained one group on a single practice problem, another group on three problems, and a third group on twenty-four problems. It is important to bear in mind that the amount of time was held constant across the three experimental groups. Thus, it would be expected that the degree of learning would be unequal among subjects. As predicted, the subjects trained on three problems did best on a transfer test, and those trained on a single problem did better than the students who were given multiple problem training.

The interpretation given these results by Morrisett and Hovland seems appropriate and also important in what it has to suggest about practice in teaching. They argue that when a method for solving problems is to be transferred, the method itself must be well learned. With limited time for practice, this learning is most thorough if the number of training problems is restricted. This would seem to account for the relatively better transfer of the subjects who were trained on one or three problems as compared with the multiple problem training group. At the same time, the fact that members of one of these groups had been provided with training on more than a single problem enabled them to respond correctly to variations in stimuli on the transfer problems. They not only were thoroughly familiar with the samples on which they were trained, but they were able to generalize across the problems.

A study by Barlow (1937) examined the influence of general training in reasoning on pupils' ability to reason about other material which is essentially unrelated to the training tasks. Barlow divided 76 seventh- and eighth-grade subjects into control and experimental groups. The two groups were matched on the basis of intelligence test scores. On the average, members of these groups were only slightly above average in intelligence, which allows Barlow's findings to be generalized more broadly than if he had selected pupils of extremely high (or low) ability.

All the pupils were given the preliminary task of writing the morals conveyed by fifteen of Aesop's fables. The experimental subjects then received a total of twelve lessons, twenty minutes being devoted to each lesson, which dealt with analysis, abstracting, and generalization. This special training consisted of four lessons on analogies, in which the subjects not only were to give their answers, but also were to try to write out the steps used by them in arriving at their solutions. Four additional lessons were devoted to abstracting and generalizing from the concrete to the general and from the general to the concrete. The final four lessons emphasized reading comprehension and the analysis of behavior. Unfortunately, Barlow does not give us a fuller account of his experimental treatment. It is not at all clear what kinds of materials the pupils dealt with in learning to generalize from the "concrete to the general and the general to the concrete," nor do we know what the "analysis of behavior" consisted of for Barlow's subjects.

When the end test was repeated, following the special training, the experimental subjects made higher transfer scores than the control subjects, suggesting that the training in reasoning did facilitate the pupils' ability to handle problem situations about which they had received no particular instruction.

There is another aspect of Barlow's study that is commendatory because of its effort to look at a practical consequence of training for transfer and also because similar data are so infrequently reported in educational investigations. Barlow reexamined his seventh- and eighth-grade subjects one year following the initial training. After a year, no differences existed between those who had been experimental and those who had been control subjects. The year-end scores of both groups are only slightly higher than the test scores of the experimental group immediately after its special lessons. Barlow explains these results by suggesting that the experimental subjects suffered a decrement attributable to forgetting the material introduced in the reasoning lessons, which was more than compensated for by the processes of maturation. The total gain made by control subjects is, according to Barlow, a function of maturation (plus their greater experience in reasoning during the elapsed year). Barlow also argues that the control subjects made no greater gains in reasoning in a year than were made by the experimental group as the result of two weeks of special training. His data seem to support this conclusion, although it is patently impossible to support the implication of his conclusion, which is that a year was required for the differences to disappear. At any rate, his contention that general training in reasoning does transfer, and substantially, to specific problems in reasoning, seems well supported.

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6

Principles for Promoting Problem-Solving Behavior in the Classroom

FROM TIME TO TIME in the preceding pages we have observed a classroom teacher in action or we have tried to point out implications of research on problem solving for the practice of teaching. In this final, summary chapter our goal is to examine more specifically the behavior of a teacher as she goes about her daily activities in the classroom. Of course, not all of this teacher's time and energy are devoted to promoting problem-solving skills, but we shall direct our attention to those aspects of her behavior which are pertinent to our previous discussion.

Miss Young is a fifth-grade teacher in a middle-class neighborhood of a large, urban school district. She graduated from college ten years ago and has been teaching in the same school ever since. She reports that she has never seriously considered finding a different teaching position since her own philosophy of teaching and that which governs the school in which she works are highly compatible with each other. The school's curriculum directives stress the integration of subject matter and the development of the pupils' intellectual independence. In the classroom, these directives tend to be implemented by the use of individual and group projects, correlation between subjects (such as the social studies and the language arts), and a great deal of what the teacher and the pupils refer to rather loosely as "research." Research, in this context, typically means use by the pupils of basic and supplementary texts, reference books, and books drawn from the school's well-stocked library to collect data on a problem currently being investigated by the pupils.

The school does not place heavy emphasis upon mastery of factual subject-matter content by the pupils. Such mastery is presumed to be a natural by-product of the teaching procedures employed by the faculty. The results of standardized achievement tests, which are administered annually, appear to support this contention. On the average, pupils score well above their present grade placement when their performances are compared with a national sample. However, it is important to bear in mind that the intelligence level of the pupils in Miss Young's classroom is also substantially higher than average, and it is not unreasonable to assume that these pupils, given ordinary access to instructional materials, will learn the kinds of fundamental information which most standardized tests call for. In schools which boast less gifted pupils, and pupils whose homes provide fewer cultural opportunities, such assumptions cannot easily be made. Awareness on the part of the school of the vital role played by intelligence and background is frequently reflected by different emphases in the curriculum and the methods of teaching used by the teachers.

A central theme of this book is that the goals of the teacher are instrumental in shaping the activities of the classroom. The significance of that statement is attested to by Miss Young's behavior, as she plans for teaching and as she conducts her class. Miss Young is clearly aware that she wants her pupils to advance in their ability to define problems for themselves, to plan and organize areas of inquiry, and to learn general techniques and skills for analyzing and solving problems as a result of the year they spend under her tutelage. These goals govern, to some extent at least, the roles of the teacher and of the pupils in the classroom. However, it is important to notice in this connection that Miss Young's intellectual goals are reinforced by those of the school. Under different circumstances the teacher could find herself in real conflict. In part, it is the consonance between her own goals and those of the school at large which allows Miss Young to behave as she does.

As part of their study of United States history, Miss Young's class is beginning a unit on westward expansion. This unit has been preceded by several others dealing with exploration, colonization, and the early years of independence. The unit activity begins with the teacher's solicitation from the pupils of questions they wish to answer or information they want to acquire about this general phase of American history. The pupils raise many and varied questions. Miss Young is at the chalkboard at the front of the room, and she jots down a key word or phrase to signify each question. The teacher has a difficult task to perform at this point. Because she knows that problem-solving behavior is goal-oriented, she is aware of the importance of having pupils undertake activities of some significance and interest to them. She is also concerned that each pupil feels his contribution is welcomed and respected. On the other hand, Miss Young regards her obligation to monitor pupils' problems as a critical part of her role. From time to time she challenges one of the pupils' questions. This is typically accomplished by telling the pupil frankly that she does not understand what he has in mind, or that she does not see how that question will fit into the unit activity. If the pupil is prepared to explain his interest in the question and can demonstrate its relationship to some broader aspect of the study, Miss Young accepts the question. Otherwise, the pupil is asked to reconsider it and place it in an altered context. These exchanges between teacher and pupil are conducted carefully, in an effort to communicate to the pupil that he is being neither rejected nor censured. Miss Young's attitude is consistently one which asks: "Is this really sufficiently important for you to devote your time and effort to?"

Later on, the questions assembled by the pupils and the teacher will be organized into a study outline, and general topics will be assigned either to individuals or to small groups of pupils. As a result of the teacher's careful planning described above, the problems that the pupils are now involved with are sufficiently broad in scope to demand considerable reading, thinking, note-taking, organizing, and synthesizing on the part of the pupils. Because Miss Young regards the development of such skills as a serious educational activity, she provides for it in a number of ways. Flexible deadlines are set early for the completion of the pupils' projects, and they are set far enough in advance that the pupils have time to complete their work intelligently. They are not pushed to the extent that they have to resort to such artifices as copying material directly from reference books or stringing together a series of unarticulated passages to give the impression of a finished report. Miss Young's interest is in the substance of the pupils' studies, not in their form.

Toward the close of each working period, Miss Young and the class routinely discuss the progress being made by the various committees and individuals. This procedure enables the teacher not only to retain an informal record of the groups' progress, but to pinpoint pupils who are having difficulty. These discussion sessions are used for sharing information as well as for reviewing progress. Pupils communicate to the classroom group difficulties they have had in locating relevant information or techniques they have developed for organizing data. Frequently, the members of one group will announce that they have come across resource material which they believe will be useful to the members of another committee. Miss Young encourages such class discussions, but she tries to focus them upon the development of generalizations about problem-solving behavior which will be of use to the pupils in the future as well as in the present.

Miss Young's efforts at developing general skills with her pupils are not restricted to the formal period of the social studies. For example, early in the year many of the pupils were encountering difficulty in taking notes from their reading and organizing the notes into an outline form which would be of some practical use to them. The teacher recognized this group limitation, and several language arts periods were devoted to the development of skills in note-taking and outlining. A few days after this, when the class was viewing a sound motion picture, the teacher encouraged the pupils to practice their new skills, suggesting to them that a set of well organized notes would provide a much more reliable record of the contents of the film than unaided memory would. Thus, Miss Young emphasized the applicability to new situations of skills and principles learned in different contexts.

The work sessions during the unit activity may take on many forms. On some days, as suggested above, the class engages in a common pursuit, such as viewing a film or reading a few pages from the basic textbook to provide the needed continuity of the unit. On other days, the period is devoted to individual or group study. At these times, Miss Young's function is principally one of counseling with individuals about their work. She may suggest various ways of getting started to one pupil who is stymied or recommend additional references to another pupil whose sources of information seem to be limited. Sometimes she may sit with one group of pupils for an extended period as they plan a division of labor and work out procedures for achieving their group goals. It may not be apparent, but all of these guiding and planning activities engaged in by the teacher make virtually endless demands upon her store of knowledge, creativity, and ability to work effectively with pupils.

At the beginning of this book we described the problem-solving process and indicated some of the implications for the teacher who would help his students develop problem-solving skills. Miss Young's behavior, as we have portrayed it thus far, illustrates these implications. She is aware that pupils must help to determine and define the activities they are going to pursue if these activities are to capture the serious interest and energy of the learners. Obviously, however, children's interests are often fleeting and capricious. Miss Young recognizes her responsibility to the pupils and to the school to build into her planning as many assurances as possible that the problems to be solved by the pupils make a significant contribution to their intellectual development, including, in this case, their knowledge and understanding of one important aspect of American history. Factors such as the amount of time available for the study, the abilities of individual pupils, and the resources of the classroom, the school, and the community also play an important part in the teacher's decisions. Miss Young's consistent attention to the work of the individuals in the classroom group enables her to channel and guide their growth in problem-solving skills. This procedure allows her to engage the pupil in private or semiprivate discussions about his work. Much in the manner of Bloom and Broder's tactics for diagnosing the problem-solving processes of successful and unsuccessful college students, Miss Young is in a position to help the pupil determine his own strengths and weaknesses, to find what is good about his proposed course of action and where the flaws in his reasoning lie.

In Chapter 3 we reviewed some of the psychological literature pertaining to the effects of group functioning upon individual responses in problem solving. One of the most pervasive findings in this literature is that the group environment plays a significant role in influencing the behavior of individuals. The reader may recall Asch's experiment with the modification of the judgments of individuals confronted by a unanimous but incorrect majority judgment, or the influence upon ultimate individual solutions to problems when minority opinions are given a careful hearing, as reported by Maier. Although we do not have firm data to demonstrate the applicability of such principles to the functioning of classroom groups, there seems little reason to doubt their applicability. Classrooms, because of their essentially public nature, would appear to be an obvious arena for the occurrence of such phenomena.

Miss Young is quite sensitive to such issues as this one. In conducting classroom discussions, particularly those in which the pupils are likely to share with others their own reasoning or original ideas for attack on a problem, the teacher is careful to protect the rights of each child to be heard by the class. Miss Young's response to pupils' contributions is basically an unevaluative one. This does not imply that all proposed solutions to problems are accepted unequivocally. Almost the reverse of this is, in fact, true. The pros and cons of an issue may be argued extensively and heatedly by the teacher and the pupils, but the arguments tend to center around the validity of the ideas.

We can only judge the adequacy of Miss Young's procedure by the classroom behavior of her pupils. The fact that pupils repeatedly enter into such discussions, unabashedly introducing their own ideas for group discussion, sometimes including those about which they are not very certain, strongly suggests that the classroom environment rewards the contributing pupil by providing a forum in which he can productively test the results of his own problem-solving efforts and in which, incidentally, he has a continuing responsibility to help create an environment which is equally reinforcing for his peers.

The work of Luchins, Miller, and Ackerman and Levin, all described previously, point to the inhibiting effects upon response production of stereotyped approaches to the solving of problems. The implications of these findings for the classroom seem to reside in emphasizing varied attacks upon problems. Ackerman and Levin, for example, discovered that pupils who were taught two possible methods for solving the Luchins water jar problems varied their attacks more systematically than the control subjects who were given but a single method for solving the problems, and they also persisted longer in attempting to solve the problems. Although it is unfortunately true that the experimental subjects did not solve significantly more problems correctly than the control subjects, the aforementioned results appear to be of considerable importance for the classroom teacher since the key to ultimately solving many problems may lie precisely in the area of continuing and varying one's efforts to crack an apparently unyielding problem.

Three characteristics of Miss Young's classroom exemplify these findings. First, the classroom résumés we mentioned earlier are intended to bring to the attention of the pupils various means for collecting and organizing data, for testing trial solutions or conclusions, many of which may not occur to the individual pupil for whom one or more suggestions will prove extremely useful. Second, as we described Miss Young's strategy in designing the unit of study, one point we touched on was the matter of deadlines for completing pupil projects. As indicated at that time, these deadlines are set early, so that each pupil knows how much time he has available and can plan to use his time as wisely as possible; but the deadlines are also flexible. Thus, the pupil who encounters early difficulty with his problems is not placed in the position of having to persevere with an unviable or unintelligent plan of operation simply in order to have a product when the final bell rings. Time is of importance in Miss Young's scheme of things, as it must be for any teacher, but it occupies a lower priority than the opportunity for the pupil to create his best solution to his problems. Finally, failure of preliminary efforts is not regarded as a disgrace by the teacher nor, consequently, by the pupils. Instead, initial failures represent experiences from which the pupil can abstract the reasons for his lack of success, using this learning as a basis for designing a potentially more productive line of attack.

A final word about classroom problem solving. The Miss Young of our illustration seems aptly to demonstrate many of the principles of problem solving developed through the first five chapters. It is true that she teaches in a situation that offers almost optimal conditions for the development of problem solving in the classroom. The pupils with whom she works possess superior intellectual ability; they come from homes that share with the teacher and the school more generally a variety of values, interests, and attitudes concerning knowledge. The teacher who works with pupils of lesser endowment may be inclined to feel that his major energy must be devoted to teaching pupils the basic rudiments of the several disciplines. But such a position seems to introduce an unwarranted dichotomy between knowledge and the intellectual skills. It is undeniable that one cannot think without relevant facts and information at his command. But of what use are the basic skills and knowledge unless they can be applied by the learner in the solution of his problems?

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